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All correspondence relating to the publication of papers **should be addressed to**

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JOURNAL

OF THE

AMERICAN WATER WORKS ASSOCIATION

Vol. 30 February, 1938 No. 2

TENTATIVE STANDARD SPECIFICATIONS FOR LAYING CAST-IRON PIPE*

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Editor's Note: This final report of sub-committee 7-D was submitted to the Committee on Water Works Practice on December 30, 1937 and to the Board of Directors of the American Water Works Association on January 19, 1938. It was approved by the Board and ordered printed in the Journal. Exceptions, if any, should be recorded in writing with the Secretary of the A.W.W.A. before March 15, 1938. In the absence of substantial criticism the report will be submitted to the Board for final approval on April 26, 1938.

INTRODUCTION

The Standard Specifications and the Addenda are intended as a guide in making extensions to existing distribution systems, and in preparing specifications for contracts for the construction of new systems or extensions.

In adapting these specifications to particular needs, they should be carefully reviewed and modified by inserting certain supplementary specifications of local application as needed to properly coordinate the basic specifications with the added specifications, to produce thereby a comprehensive contractual agreement between the owner and the contractor.

The Addenda which follow Standard Specifications supplement them in respect to optional clauses or alternatives of procedure. The desired procedure will be selected from the Addenda and incorporated in the Specifications.

Limits: These specifications *cover* all procedure in laying, testing and chlorinating a system of bell-and-spigot cast-iron pipes for water works; the furnishing of sheeting, blocking, backing, joint materials and sterilizing agents.

These specifications *do not cover* the furnishing and delivery of pipes, castings, fittings, valves, hydrants or the laying and jointing of any other kind of pipe, or the use of any other type of joint, nor the items to be added under supplementary specifications listed below.

Supplementary Specifications must be added to the Standard Specifications defining and qualifying certain items of work peculiar to individual projects or localities that may not be incorporated in Standard Specifications such as:

General Conditions of the Contractual Agreement.
Materials furnished by Contractor.
Measurement and payment for work on a unit price basis.
Measurement and payment for extra work.
Pavement, when replaced by the Contractor.
Safety and public health regulations of the locality.
Engineering design of special features.
Depth of cover, if not shown on drawings. See Section 6.3.
Maintenance period, if different from that required in Section 16.27.

Publication of the "Standard Specifications For Laying Cast-Iron Pipe" and the "Addenda" other than by printed form to be

attached in the Contract Documents would be unnecessary if the Engineer, after defining the scope of the work contemplated in Section 1, should write under the title "Specifications" words having the following import:

> The pipe shall be laid and the work incidental thereto performed in accordance with Standard Specifications of the American Water Works Association for Laying Cast-Iron Pipe hereto attached, including certain requirements selected from the optional clauses of the Addenda to Standard Specifications hereinafter referred to by Section Numbers of the Addenda. Such as for example:
>
> Sect. 2.01 Materials, By whom furnished.
> Sect. 2.20 Blocking.
> Sect. 2.32 Jointing material.
> Sect. 2.40 a Chlorination.
> Sect. 2.50 Water for Construction Purposes.
> Sect. 2.60 a Paving.
>
> and also in accordance with the following Supplementary Specifications: (insert here supplementary specifications defining and qualifying items to be incorporated and Sect. 1.1 to 1.32 as listed below.)

Section 1—Scope

These general and detailed specifications form a part of the Contract Documents and shall govern the handling and installation of bell-and-spigot cast-iron pipe, valves, hydrants, and accessories described in Sect. 1.1 to Sect. 1.32, and as shown on the accompanying plans.

Sect. 1.1 General description and schedule of work to be performed.
Sect. 1.2 List of contract drawings.
Sect. 1.3 Estimated quantities.
Sect. 1.31 Additional quantity items.
Sect. 1.32 Special work items.

Sect. 1.4 *Work Included:* All labor, equipment and material necessary to complete the work as specified in Sections 1.1 to 1.32 inclusive. The Contractor shall remove so much of the pavement as may be necessary; excavate the trenches and pits to the required dimensions; excavate the bell holes; construct and maintain all bridges required for traffic control; sheet, brace and support the

adjoining ground or structures where necessary; handle all drainage or ground water; guard the site; unload, haul, distribute, lay and test the pipe, fittings, valves, hydrants, and accessories; rearrange the branch connections to main sewers, or rearrange other conduits, ducts, or pipes where necessary; replace all damaged drains, sewers, or other structures; backfill the trench and pits; restore the roadway surface unless otherwise stipulated; remove surplus excavated material; clean the site of the work; chlorinate the completed pipe line; and maintain the street or other surface over the trenches.

Section 2—Specific Statement of Alternatives

See Addenda following section 18.

Section 3—Inspection

Sect. 3.1 *Of Materials at Factory:* All materials, whether furnished by the Owner or by the Contractor, are subject at the discretion of the Owner, to inspection and approval at the plant of the manufacturer.

Sect. 3.2 *Of Materials at Delivery Point:* During the process of unloading, all pipe and accessories shall be inspected by the Contractor for loss or damage in transit. No shipment of material shall be accepted by the Contractor until or unless notation of any lost or damaged material shall have been made on the bill of lading by the agent of the carrier.

Sect. 3.3 *Field Inspection:* All pipe and accessories shall be laid, jointed, tested for defects and for leakage with pressure and chlorinated in the manner herein specified in the presence of the Engineer or his authorized Inspector, and subject to their approval.

Sect. 3.31 *Disposition of Defective Material:* All material found during the progress of the work to have cracks, flaws, or other defects will be rejected by the Engineer, and the Contractor shall promptly remove from the site of the work such defective material.

Section 4—Contractor's Responsibility for Material

Sect. 4.1 *Responsibility For Material Furnished by Contractor:* The Contractor shall be responsible for all material furnished by him and he shall replace at his own expense all such material that is found to be defective in manufacture or that has become damaged in handling after delivery by the manufacturer.

Sect. 4.2 *Responsibility For Material Furnished by Owner:* The

Contractor's responsibility for material furnished by the Owner shall begin at the point of delivery by the manufacturer, or Owner, and upon acceptance of the material by the Contractor. The Contractor shall examine all material furnished by the Owner at the time and place of delivery, and shall reject all defective material. Any defective material furnished by the Owner and not rejected by the Contractor, and discovered prior to final acceptance of the work, will be replaced with sound material by the Owner and the Owner will furnish such additional material and supplies as may be necessary to install such replaced material; the Contractor, however, shall remove the defective material and install the replaced material at his own expense, furnishing all the labor and facilities necessary to complete the work to the satisfaction of the Engineer.

Sect. 4.3 *Replacement of Damaged Material:* Any material furnished by the Owner that becomes damaged after acceptance by the Contractor, shall be replaced by the Contractor at his own expense.

Sect. 4.4 *Responsibility For Safe Storage:* The Contractor shall be responsible for the safe storage of material furnished by or to him, and accepted by him, and intended for the work, until it has been incorporated in the completed project.

Section 5—Handling Pipe and Accessories

Sect. 5.1 *Care:* Cast iron pipe, fittings, valves, hydrants, and other accessories shall, unless otherwise directed, be unloaded at the point of delivery, hauled to and distributed at the site of the project by the Contractor; they shall at all times be handled with care to avoid damage. In loading and unloading they shall be lifted by hoists or slid, or rolled on skidways in such manner as to avoid shock. Under no circumstances shall they be dropped. Pipe handled on skidways must not be skidded or rolled against pipe already on the ground.

Sect. 5.2 *At Site of Work:* In distributing the material at the site of the work, each piece shall be unloaded opposite or near the place where it is to be laid in the trench.

Sect. 5.3 *Care of Pipe Coating:* Pipe shall be handled in such a manner that a minimum amount of damage to the coating will result. Damaged coating shall be repaired in a manner satisfactory to the Engineer.

Sect. 5.4 *Bell Ends, How Faced:* Pipe shall be placed on the site of the work parallel with the trench alignment and with bell

ends facing the direction in which the work will proceed unless otherwise directed.

Sect. 5.5 *Pipe Kept Clean:* The interior of all pipe, fittings, and other accessories shall be kept free from dirt and foreign matter at all times.

Sect. 5.6 *Frost Protection:* Valves and hydrants before installation shall be drained and stored in a manner that will protect them from damage by freezing.

Section 6—Alignment and Grade

Sect. 6.1 *General:* All pipe shall be laid and maintained to the required lines and grades; with fittings, valves, and hydrants at the required locations; and with joints centered and spigots home; and with all valve and hydrant stems plumb.

Sect. 6.11 *Protecting Underground and Surface Structures:* Temporary support, adequate protection and maintenance of all underground and surface utility structures, drains, sewers, and other obstructions encountered in the progress of the work shall be furnished by the Contractor at his own expense under the direction of the Engineer.

Sect. 6.12 *Deviations Occasioned by Other Utility Structures:* Wherever existing utility structures or branch connections leading to main sewers or to main drains, or other conduits, ducts, pipes, or structures present obstructions to the grade and alignment of the pipe, they shall be permanently supported, removed, relocated, or reconstructed by the Contractor through coöperation with the owner of the utility, structure, or obstruction involved. In those instances where their relocation or reconstruction is impracticable, a deviation from line and grade will be ordered, and the change shall be made in the manner directed, and with extra compensation allowed therefor.

Sect. 6.13 *Deviation With Engineer's Consent:* No deviation shall be made from the required line or grade except with the written consent of the Engineer.

Sect. 6.2 *Subsurface Explorations:* Whenever necessary to determine the location of existing pipes, valves, or other underground structures, the Contractor, after an examination of available records and upon the written order of the Engineer, shall make all explorations and excavations for such purpose; the Engineer will allow extra compensation therefor.

Sect. 6.3 *Depth of Pipe Cover:* All pipe shall be laid to the depth shown on the Contract Drawings or as required in Supplementary Specifications, measured from the established street grade or the surface of the permanent improvement to the top of the barrels of the pipe.*

Section 7—Excavation and Preparation of Trench

Sect. 7.1 *Description:* The trench shall be dug to the alignment and depth required (Section 6.3) and only so far in advance of pipe laying as the Engineer shall permit. The trench shall be so braced (Section 7.5) and drained that workmen may work therein safely and efficiently. It is essential that the discharge from pumps be led to natural drainage channels, to drains, or to sewers.

Sect. 7.11 *Width:* The trench width may vary with and depend upon the depth of trench and the nature of the excavated material encountered; but in any case shall be of ample width to permit the pipe to be laid and jointed properly and the backfill to be placed and compacted properly. The minimum width of unsheeted trench shall be 18 inches, and for pipe 10 inches or larger, at least one foot greater than the nominal diameter of the pipe, except by consent of the Engineer; the maximum clear width of trench shall be not more than two feet greater than the pipe diameter.

Sect. 7.2 *Pipe Foundation in Good Soil:* The trench, unless otherwise specified under Section 9, shall have a flat bottom conforming to the grade to which the pipe is to be laid. The pipe shall be laid upon sound soil cut true and even, so that the barrel of the pipe will have a bearing for its full length. See Footnote under Sect. 9.1.

* The minimum depth of cover over water pipe should be determined by: (1) the maximum depth of frost penetration in the locality where the pipe is to be laid, and (2) the direct effect of loaded trucks.

The depth of cover selected becomes one of the factors in the determination of metal thickness as affected by surface loads, impact, operating pressures, water hammer, and their relationships.

The minimum cover in these circumstances may be taken as 3 feet; however 5 feet is desirable if the effect of truck loads and impact is to be avoided in the design of the pipe.

Where failures in cast-iron pipe lines occur, they usually result from settlement, careless laying, flat slope trenching, bedding on rock, improper backfilling procedure, impact from vehicles resulting from having laid the pipe too shallow, or rupture from freezing for the same reason. These and other external and internal hazards should be carefully considered before the line is laid.

Sect. 7.21 *Correcting Faulty Grade:* Any part of the trench excavated below grade shall be corrected with approved material, thoroughly compacted.

Sect. 7.22 *Pipe Foundation in Poor Soil:* When the bottom uncovered at sub-grade is soft and in the opinion of the Engineer, cannot support the pipe, a further depth and/or width shall be excavated and refilled to pipe foundation grade as required under Section 7.21, or other approved means shall be adopted to assure a firm foundation for the pipe with extra compensation allowed therefor.

Sect. 7.3 *Pipe Clearance in Rock:* Ledge rock, boulders, and large stones shall be removed to provide a clearance of at least six inches below all parts of the pipe, valves, or fittings, and to a clear width of six inches on each side of all pipe and appurtenances for pipes 16 inches or less in diameter; for pipes larger than 16 inches, a clearance of 9 inches below and a clear width of 9 inches on each side of pipe shall be provided. Adequate clearance for properly jointing pipe laid in rock trenches shall be provided at bell holes.

Sect. 7.31 *Sub-grade in Rock Trench:* Excavations below subgrade in rock or in boulders shall be refilled to sub-grade with approved material, thoroughly compacted.

Sect. 7.32 *Rock Excavation Defined:* Rock excavation shall include all ledge rock in place that cannot be excavated by hand without blasting and also all boulders or rock fragments whose volume is 9 or more cubic feet.

Sect. 7.33 *Blasting Procedure:* Blasting for excavation will be permitted only after securing the approval of the Engineer and only when proper precautions are taken for the protection of persons or property. The hours of blasting will be fixed by the Engineer. Any damage caused by blasting shall be repaired by the Contractor at his expense. The Contractor's methods of procedure relative to blasting shall conform to local state laws and municipal ordinances.

Sect. 7.4 *Bell Holes Required:* Bell holes of ample dimensions shall be dug in earth trenches at each joint to permit the jointing to be made properly.

Sect. 7.5 *Braced and Sheeted Trenches:* Wherever necessary to prevent caving, excavations in sand, gravel, sandy soil, or other unstable material shall be adequately sheeted and braced. Where sheeting and bracing are used, the trench width shall be increased accordingly. Trench sheeting shall remain in place until the pipe has been laid, tested for defects and repaired if necessary, and the

earth around it compacted to a depth of two feet over the top of the pipe.

Sect. 7.6 *Care of Surface Material For Re-use:* If local conditions permit their re-use, all surface materials suitable for re-use in restoring the surface shall be kept separate from the general excavation material.

Sect. 7.61 *Manner of Piling Excavated Material:* All excavated material shall be piled in a manner that will not endanger the work and that will avoid obstructing sidewalks and driveways. Gutters shall be kept clear or other satisfactory provisions made for street drainage.

Sect. 7.7 *Trenching By Machine Or By Hand:* The use of trench-digging machinery will be permitted except in places where operation of same will cause damage to trees, buildings, or existing structures above or below ground; in which case hand methods shall be employed.

Sect. 7.8 *Barricades, Guards and Safety Provisions:* To protect persons from injury and to avoid property damage, adequate barricades, construction signs, torches, red lanterns and guards as required shall be placed and maintained during the progress of the construction work and until it is safe for traffic to use the trenched highway. Whenever required, watchmen shall be provided to prevent accidents and extra compensation will be allowed therefor. Rules and regulations of the local authorities respecting safety provisions shall be observed.

Sect. 7.9 *Traffic and Utility Controls:* Excavations for pipe laying operations shall be conducted in a manner to cause the least interruption to traffic. Where traffic must cross open trenches, the Contractor shall provide suitable bridges at street intersections and driveways. Hydrants under pressure, valve pit covers, valve boxes, curb stop boxes, fire or police call boxes, or other utility controls shall be left unobstructed and accessible during the construction period.

Sect. 7.91 *Flow of Drains and Sewers Maintained:* Adequate provision shall be made for the flow of sewers, drains and water courses encountered during construction, and the structures which may have been disturbed shall be satisfactorily restored upon completion of the work.

Sect. 7.92 *Property Protection:* Trees, fences, poles, and all other property shall be protected unless their removal is authorized; and any property damaged shall be satisfactorily restored by the Contractor.

Sect. 7.93 *Interruption of Water Service:* No valve or other control on the existing system shall be operated for any purpose by the Contractor without approval of the Engineer, and all consumers affected by such operation shall be notified by the Contractor at least one hour before the operation and advised of the probable time when the service will be restored.

Section 8—Pipe Laying

Sect. 8.1 *Manner of Handling Pipe and Accessories into Trench:* Proper implements, tools, and facilities satisfactory to the Engineer shall be provided and used by the Contractor for the safe and convenient prosecution of the work. All pipe, fittings, valves, and hydrants shall be carefully lowered into the trench piece by piece by means of derrick, ropes, or other suitable tools or equipment, in such manner as to prevent damage to pipe or pipe coating. Under no circumstances shall pipe or accessories be dropped or dumped into the trench.

Sect. 8.2 *Hammer Test:* Before lowering and while suspended, the pipe shall be inspected for defects and rung with a light hammer to detect cracks. Any defective, damaged, or unsound pipe shall be rejected.

Sect. 8.3 *Pipe Kept Clean:* All foreign matter or dirt shall be removed from the inside of the pipe before it is lowered into its position in the trench, and it shall be kept clean by approved means during and after laying.

Sect. 8.4 *Laying the Pipe:* Unless the Engineer shall permit otherwise, after placing a length of pipe in the trench, the yarning material for the joint shall be held around the bottom of the spigot, so that it will enter the bell as the pipe is shoved into position.

The spigot shall be centered in the bell, the pipe forced "home", and brought into true alignment; it shall be secured there with earth carefully tamped under and on each side of it, excepting at the bell holes. Care shall be taken to prevent dirt from entering the joint space.

Sect. 8.41 *Number of Pipes Laid Before Jointing:* Whenever the jointing material specified is sulphur compound, two or more lengths of pipe shall be in place ahead of each joint before it is poured. Whenever the jointing material specified is cement, four or more lengths of pipe shall be in place ahead of each joint as it is finished. (For cement joints, six lengths are preferred.)

Sect. 8.42 *Preventing Trench Water From Entering Pipe:* At

times when pipe laying is not in progress, the open ends of pipe shall be closed by approved means, and no trench water shall be permitted to enter the pipe.

Sect. 8.5 *Cutting Pipe:* Cutting of pipe for inserting valves, fittings, or closure pieces shall be done in a neat and workmanlike manner without damage to the pipe.

Sect. 8.6 *Bell Ends To Face Direction of Laying:* Unless otherwise directed, pipe shall be laid with bell ends facing in the direction of laying; and for lines on an appreciable slope, bells shall, at the discretion of the Engineer, face up-grade.

Sect. 8.7 *Permissible Deflections at Joints*:* Wherever necessary to deflect pipe from a straight line, either in the vertical or horizontal plane to avoid obstructions, to plumb stems, or for other reasons, the degree of deflection shall be approved by the Engineer.

Sect. 8.8 *Railroad Crossing:* When any railroad is crossed, all precautionary construction measures required by the railroad officials shall be followed and the Engineer shall allow extra compensation therefor, unless otherwise provided.

Sect. 8.9 *Unsuitable Conditions For Laying Pipe:* No pipe shall be laid in water, or when the trench conditions or the weather is unsuitable for such work, except by permission of the Engineer.

Section 9—Blocking Pipe†

See Addenda, Sect. 2.20.

Sect. 9.1 *General:* Pipe 16 inches or larger in diameter shall, if ordered by the Engineer, be laid on wood blocks and held in position by wood wedges.

* A practice considered conservative allows a deflection that permits one side of the Spigot end of the pipe to be away from home when the other side is touching the hub of the bell, a distance not exceeding $\frac{3}{4}$-inch in pipes larger than 12 inches, and not more than $\frac{1}{2}$-inch for pipes 12 inches or smaller.

† Wherever conditions permit, the type of pipe foundation described in Section 7.2 is preferable to the alternative specified under Section 9, entitled "Blocking Pipe" Experiments indicate that the walls of a pipe supported by blocks must be thicker in order to stand the same internal pressure and external loads than one laid on a flat bottom trench. There appears to be no doubt that the bearing strength of pipe laid on a flat bottom trench, well-tamped or puddled, is considerably greater than if the pipe is laid and continues to bear on blocking. Consideration must be given to type of trench, method of backfilling, and use of blocks, if any, when specifying metal thickness of pipe required in any particular installation. Other factors affecting pipe thickness such as water hammer, excessive earth loads, truck loads, foundry tolerance, and corrosion should also be considered.

Sect. 9.2 *Dimensions:* Blocking and wedges shall be cut from sound lumber and sized according to a schedule varying with the pipe diameter to be supplied by the Engineer. Unless otherwise specified, blocks shall be at least 4 inches longer than the nominal pipe diameter and shall be made from lumber whose least dimension is 2 inches x 8 inches, and wedges shall be made from 4 inch x 6 inch lumber about 6 inches long.

Sect. 9.3 *Number of Blocks:* There shall be two blocks supporting each length of pipe with center line of blocks spaced 3 feet on either side of bell joint for pipes 12 feet long, 4 feet for pipes 16 feet long, 4½ feet for pipes 18 feet long, and 5 feet for pipes 20 feet long.

Sect. 9.4 *Alignment and Grade:* Blocks shall be bedded firmly with uniform bearing and shall be level across the bottom of the trench. The trench shall be excavated at least one inch below grade and the blocks shall project at least one inch above the trench bottom; they shall be aligned to the proper grade.

Section 10—Jointing Pipe

Sect. 10.1 *Preparation of Pipe Ends:* Before laying the pipes, all lumps, blisters, and excess coal-tar coating shall be removed from the bell-and-spigot ends of each pipe; the pipe ends shall then be wire brushed and wiped until clean and dry. Where sulphur compound or cement jointing material is specified, oil and grease also shall be removed. Pipe ends shall be kept clean until joints are made.

Sect. 10.2 *Jointing Material Alternatives:* Pipe joints shall be sealed with either lead, sulphur compound, or with Portland cement as required, following the preparation of the joint base with yarning material as hereinafter specified.

Sect. 10.3 *Sterilized Yarning Materials:* All hemp, jute or other yarning material shall be free from oil, greasy substances, or tar, and shall be sterilized by boiling in water, or by means of pressure steam, or by suitable chemical agents. After sterilization it shall be kept free from contamination and applied dry. (The sterilizing should preferably be done by the manufacturer.)

Sect. 10.31 *Yarning Material For Lead, Sulphur Compound or Cement Joints:* (a) For lead joints, either braided hemp, or untarred twisted jute, or other suitable material which has the approval of the Engineer, may be used.

(b) For sulphur compound joints, only square braided hemp or

jute, or other suitable material which has the approval of the Engineer, shall be used.

(c) For cement joints, braided hemp or jute, and untarred twisted jute, or other suitable material which has the approval of the Engineer, shall be used, unless the Engineer shall order the omission of yarning material.

Sec. 10.32 *Length of Yarning Material Strands:* Wherever a single strand of braided hemp or jute, or other suitable yarning material is required in jointing, the material shall be cut to such length that the strand will reach entirely around the pipe with ends overlapping not less than two inches. Wherever more than a single strand of braided hemp or jute, or other suitable yarning material is required, it shall be cut to sufficient length so that the ends meet without causing overlap. Those ends should meet on opposite sides of the pipe and not on the top or bottom.

Sect. 10.33 *Procedure:* Braided hemp or jute, or other suitable yarning material shall be of proper dimension to center the spigot in the bell. Successive strands of yarning material, as required, shall be driven home separately. Each strand shall be thoroughly packed and hammered into the joint with suitable yarning tools.

Sect. 10.34 *Depth of Jointing Material:* For lead joints a space not less than 2¼ inches in depth shall be left in the bell in pipe having a nominal diameter of 20 inches or less, 2½ inches for 24, 30 and 36-inch pipe and 3 inches for pipe larger than 36-inch. For sulphur compound joints a space not less than 2½ inches in depth shall be left in the bell in pipe whose nominal diameter is 24 inches or less, 2¾ inches in depth for 30 and 36-inch pipe, 3½ inches for 48-inch pipe and 4 inches for 54 and 60-inch pipe. When cement is specified the joint space shall be not less than 3 inches in depth.

Sect. 10.4 *Specifications For Lead:* Lead for calking purposes shall contain not less than 99.73 per cent pure lead. Impurities shall not exceed the following limits:

	per cent
Arsenic, Antimony and Tin together	0.015
Copper	0.08
Zinc	0.002
Iron	0.002
Bismuth	0.25
Silver	0.02

The producer's name or identification mark shall be clearly cast or stamped upon each piece of lead.

Sect. 10.41 *Proper Heat for Lead:* Lead shall be heated in a melting pot kept near the joint to be poured, brought to a proper temperature such that when stirred it will show a rapid change of color and that when poured into the joint space it will insure a perfect joint. Before pouring, all scum shall be removed.

Sect. 10.42 *Position of Joint Runner:* The joint runner shall fit snugly against the face of the bell and the outside of the pipe, and shall be dammed with clay at the pouring gate to provide for filling the joint even with the top of the bell.

Sect. 10.43 *Joints Made With Single Pour:* Each joint shall be made with one pour, filling the joint space.

Sect. 10.44. *Calking Lead Joints:* After cooling to the temperature of the pipe, lead joints shall be calked by means of pneumatic tools, or by hand tools, by competent workmen until thoroughly compacted, making watertight joints without overstraining the bells.

Sect. 10.5 *Sulphur Compound Joints:* Compound for pipe joints shall be of approved make and of established reputation. It shall have a sulphur base and other ingredients properly proportioned to produce a workable compound, and tight and permanent joints.

Sect. 10.51 *Manufacturer's Instructions To Be Followed:* The compound shall be heated in a melting furnace suitable for the use of sulphur compound and manipulated in accordance with the instructions of the manufacturer of the compound.

Sect. 10.52 *Proper Condition For Pouring:* It shall be stirred thoroughly and continuously while melting, and until used. When poured it must be very liquid, free from froth or bubbles or any foreign matter and shall show a mirror-like surface.

Sect. 10.53 *Making the Joint:* Suitable funnel-shaped metal pouring gates extending not less than 8 inches above the bell shall be adequately clayed to the joint runner. The joint space and gate shall be filled with one continuous pour while the compound is at the proper temperature. The solidified compound in the pouring gate shall be cut off flush with the top of the bell or broken off flush with the top of the joint.

Sect. 10.54 *Replacing Defective Joints:* If a joint is defective, it shall be cut out and entirely replaced as directed by the Engineer.

Sect. 10.55 *Burned Compound Rejected:* Any compound burned in the melting pot shall be dumped out and not re-used.

Sect. 10.6 *Portland Cement Joints:*

Sect. 10.61 *Cement Specifications:* All cement shall be Portland

cement and shall comply with the current specifications of the American Society for Testing Materials.

Sect. 10.62 *Proportions of Cement and Water:* After yarning, the joint space shall be filled with neat cement barely moistened (about $\frac{1}{4}$ pint of water to 1 quart of cement) which shall be calked by competent workmen until it is as compact as possible. This cement shall be so dry that it will ring with a metallic sound while being calked.

Sect. 10.63 *Cause for Rejection:* No cement shall be used after having been wet more than one hour, or after initial set.

Sect. 10.64 *Trench Water and Initial Set:* No joint shall be made in a wet trench and no water shall be allowed to touch the joint until the initial set has taken place.

Sect. 10.65 *Joints Kept Moist Until Set:* Cement joints shall be covered immediately with slightly moist earth, or with damp burlap, for the proper time to insure complete hydration.

Sect. 10.66 *Time Interval Before Filling Pipe:* Pipe laid with cement joints shall not be filled with water until the lapse of 12 hours after the last joint in any valved section shall have been made, and pressure shall not be permitted in the pipe until all joints have aged as provided in Section 15.32.

Section 11—Setting Valves, Valve Boxes, Fittings, and Blow-Offs

Sect. 11.1 *General:* Gate valves and pipe fittings shall be set and jointed to new pipe in the manner heretofore specified for cleaning, laying, and jointing pipe.

Sect. 11.2 *Valve Boxes and Valve Pits:* Cast iron valve boxes shall be firmly supported, and maintained centered and plumb over the wrench nut of the gate valve, with box cover flush with the surface of the finished pavement or at such other level as may be directed. All geared valves and such other valves as may be designated shall be set in masonry valve pits with the wrench nuts readily accessible for operation through the manhole opening. Pits shall be constructed in a manner that will permit minor valve repairs and to afford protection to the pipe from impact where it passes through the pit walls.

Sect. 11.3 *Back-siphonage To Be Prevented:* Drainage branches or blow-offs shall not be connected to any sewer or submerged in any stream or be installed in any other manner that will permit back-siphonage into the distribution system.

Section 12—Setting Hydrants

Sect. 12.1 *General Location:* Hydrants shall be located in a manner to provide complete accessibility, and in such manner that the possibility of damage from vehicles or injury to pedestrians will be minimized. Unless otherwise directed the setting of any hydrant shall conform to the following:

Sect. 12.11 *Location Re-Curb Lines:* When placed behind curb the hydrant barrel shall be set so that no portion of the pumper or hose nozzle cap will be less than 6 inches nor more than 12 inches from the gutter face of the curb, or less than 20 feet from the curb line intersection of any street; if set between streets the hydrant shall be placed in the manner designated by the Engineer.

Sect. 12.12 *Location Re-Sidewalk:* When set in the lawn space between the curb and the sidewalk, or between the sidewalk and the property line, no portion of the hydrant or nozzle cap shall be within 6 inches of the sidewalk.

Sect. 12.2 *Position of Nozzles:* All hydrants shall stand plumb, and shall have their nozzles parallel with or at right angles to the curb, with the pumper nozzle pointing normal to the curb, except that hydrants having hose nozzles at an angle of 45 degrees shall be set normal to the curb. They shall conform to the established grade, with nozzles at least 12 inches above the ground.

Sect. 12.3 *Connection to Main:* Each hydrant shall be connected to the main pipe with a 6-inch cast iron branch controlled by an independent 6-inch gate valve, except as otherwise directed.

Sect. 12.4 *Drainage at Hydrant:* Wherever hydrants are set in impervious soil a drainage pit two feet in diameter and two feet deep shall be excavated below each hydrant and filled compactly with coarse gravel or broken stone mixed with coarse sand, under and around the bowl of the hydrant and to a level 6 inches above the waste opening. No hydrant drainage pit shall be connected to a sewer.

Sect. 12.5 *Anchorage for Hydrant:* The bowl of each hydrant shall be well braced against unexcavated earth at the end of the trench with stone slabs or concrete backing, or it shall be tied to the pipe with suitable rods or clamps.

Sect. 12.6 *Cleaning:* Hydrants shall be thoroughly cleaned of dirt, or foreign matter before setting.

Section 13—Plugging Dead Ends

Standard plugs shall be inserted into the bells of all dead ends of pipes, tees, or crosses, and spigot ends shall be capped. Plugs or caps shall be jointed to the pipe or fitting in the manner specified under Section 10.

Section 14—Anchorage of Bends, Tees, and Plugs

Sect. 14.1 *Limiting Pipe Diameter and Degree of Bend:* On all pipe lines 8-inches in diameter or larger, all tees, plugs, caps, and bends exceeding 22½ degrees shall be securely anchored by suitable thrust backing as hereinafter specified or by metal harness.

Sect. 14.2 *Material for Reaction Backing:* Reaction or thrust backing shall be of concrete of a mix not leaner than 1 cement, 2½ sand, 5 stone, having compressive strength of not less than 2,000 pounds per square inch. Backing shall be placed between solid ground and the fitting to be anchored; the area of bearing on pipe and on ground in each instance shall be that required by the Engineer. The backing shall, unless otherwise directed, be so placed that the pipe and fitting joints will be accessible for repair.

Sect. 14.3 *Metal Harness:* Metal harness of tie rods and pipe clamps of adequate strength to prevent movement, or other suitable means may be used instead of concrete backing, as directed by the Engineer. Steel rods and clamps shall be galvanized, or otherwise rust-proof treated, or shall be painted as directed by the Engineer.

Section 15—Hydrostatic Tests

Sect. 15.1 *Pressure During Test:* After the pipe has been laid and partially backfilled as specified in Section 16.1 all newly laid pipe, or any valved section of it shall, unless otherwise specified, be subjected to hydrostatic pressure 50 per cent above normal operating pressure.

Sect. 15.11 *Duration of Pressure Test:* The duration of each pressure test shall be at least 30 minutes.

Sect. 15.12 *Procedure:* Each valved section of pipe shall be slowly filled with water and the specified test pressure, measured at the point of lowest elevation, shall be applied by means of a pump connected to the pipe in a satisfactory manner. The pump, pipe connection and all necessary apparatus except gauges and meters shall be furnished by the Contractor. The Owner will furnish

gauges and measuring devices for the test and will make all taps into the pipe, but the Contractor shall furnish all necessary assistance for conducting the tests.

Sect. 15.13 *Expelling Air Before Test:* Before applying the specified test pressure, all air shall be expelled from the pipe. To accomplish this, taps shall be made, if necessary, at points of highest elevation, and afterward tightly plugged.

Sect. 15.14 *Examination Under Pressure:* All exposed pipes, fittings, valves, hydrants and joints will be carefully examined during the open trench test. Where the joints are made with lead all such joints showing visible leaks shall be recaulked until tight. Where the joints are made with sulphur compound or with cement and show seepage or slight leakage, only such joints as may be defective shall be cut out and replaced, at the Contractor's expense, as directed by the Engineer. Any cracked or defective pipes, fittings, valves or hydrants discovered in consequence of this pressure test shall be removed and replaced by the Contractor with sound material in the manner provided under Section 4 and the test shall be repeated until satisfactory to the Engineer.

Sect. 15.2 *Permissible Leakage*:* Suitable means shall be provided by the Contractor for determining the quantity of water lost by leakage under normal operating pressure. No pipe installation will be accepted until or unless this leakage (evaluated on a pressure basis of 150 lbs. per square inch) is less than 100 gallons per 24 hours per mile of pipe per inch nominal diameter for pipe in 12-foot lengths, 75 gallons for 16-foot lengths, and correspondingly varied for other lengths of pipe. In calculating leakage the Engineer will make allowance for added joints in the pipe line above those incidental to normal unit lengths of pipe.

* It is an established fact that sulphur compound joints will seep in the early stages of their life, but will "take up" as they age. The degree of seepage is more or less dependent upon two factors: namely, age and pressure. These specifications for controlling leakage are intended to apply to ordinary operating pressures usually less than 150 pounds per square inch. It is not unusual for tests to show greater leakage as pressure is increased nor for tests to show less leakage after the lapse of time. Tests made immediately after the completion of a pipe line laid with sulphur compound joints showing a relatively high rate of leakage are not at all indicative of the ultimate tightness of that line. Ordinary meters may not be suited to the measurement of leakage because of the probable slip that accompanies very low rates of flow.

The evaluation of actual leakage to standard pressure (150 #) leakage is calculated by the application of the ratio determined from the square root of respective pressures, other factors being equal.

Sect. 15.21 *Variation from Permissible Leakage:* Should any test of combined sections of pipe laid disclose leakage per mile of pipe greater than that specified in Section 15.2, or if individual sections show leakage greater than 25 percent above the specified limit, the Contractor shall at his own expense locate and repair the defective joints until the leakage is within the specified allowance.

Sect. 15.22 *Leakage Defined:* Leakage is defined as the quantity of water to be supplied into the newly laid pipe, or any valved section of it, necessary to maintain the specified leakage test pressure after the pipe has been filled with water and the air expelled.

Sect. 15.3 *Time for Making Test of Lead Jointed Pipe:* Pipes jointed with lead may be subjected to hydrostatic pressure, inspected, and tested for leakage at any convenient time after partial completion of backfill according to Section 16.1.

Sect. 15.31 *Time for Making Test of Sulphur Compound Jointed Pipe:* Pipes jointed with sulphur compound may be subjected to hydrostatic pressure at any convenient time after partial completion of backfill. Before the replacement of permanent paving and not less than thirty nor more than forty days after the pressure test, a measured leakage test shall be made of the entire pipe line. Leakage loss shall be within the allowance specified in Section 15.2. The pipe line shall be left full of water under pressure for the 30 to 40-day period between the initial pressure test and the final measured leakage test.

Sect. 15.32 *Time for Making Test of Cement Jointed Pipe:* Pipes jointed with cement shall be subjected to hydrostatic pressure following a lapse of not less than 36 hours after the last joint shall have been made, unless the Engineer shall authorize a lesser period, and shall be aged at least two weeks before testing for leakage. Leakage allowance shall be that specified in Section 15.2.

Section 16—Backfilling, Cleaning Up, and Maintaining Surfaces

Sect. 16.1 *Backfill Procedure at Pipe Zone:* Selected backfill material free from rock or boulders shall be deposited in the trench simultaneously on both sides of the pipe for the full width of the trench and to an elevation of at least 6 inches above the top of the barrels of pipes 8 inches or less in diameter, and not less than 6 inches above the horizontal center line of pipes with diameters 12 inches or larger, leaving the joints exposed for examination during the pressure test specified in Section 15. The backfill material shall be moistened if necessary, tamped in thin (about 4-inch) layers, and thoroughly

compacted under and on each side of the pipe to provide solid backing against the external surface of the pipe.

Sect. 16.2 *Backfill Procedure Above Pipe Zone:* Succeeding layers of backfill may contain coarser materials, and shall be compacted thoroughly by puddling with hose and long pipe nozzle, or by flooding the trench, or by tamping if the material does not puddle readily. (Note exception in Section 16.23.) It is important that proper precautions be taken to prevent floating of the pipe when flooding the trench, and the Contractor shall be wholly responsible for neglect of these precautions.

Sect. 16.21 *Rock and Boulder Exclusion:* No rock or boulders shall be used in the backfill for at least one foot above the top of the pipe and no stone larger than 8 inches in its greatest dimension shall be used in the backfilling.

Sect. 16.22 *Procedure Where Settlement is Important:* Where it is important that the surface of the backfill be made safe for vehicular traffic as soon as possible, or where a permanent pavement is to be placed within a short time, the upper 12 inches of backfill shall be of approved moist material, thoroughly compacted in thin (about 4-inch) layers by tamping, and shall be brought to the required surface grade.

Sect. 16.23 *Procedure Where Settlement is Unimportant:* Wherever, in the opinion of the Engineer, surface settlement is not important, tamping may be omitted in the layers above those described under Section 16.1; and the backfill shall be neatly rounded over the trench to a sufficient height to allow for settlement to grade after consolidation.

Sect. 16.24 *Deficiency of Backfill, By Whom Supplied:* Any deficiency in the quantity of material for backfilling the trenches, or for filling depressions caused by settlement, shall be supplied by the Contractor.

Sect. 16.25 *Restoration of Surface:* The Contractor shall replace all surface material, and shall restore paving (unless otherwise stipulated), curbing, sidewalks, gutters, shrubbery, fences, sod, and other surfaces disturbed, to a condition equal to that before the work began, furnishing all labor and material incidental thereto. In restoring paved surfaces, new pavement is required, except that granite paving blocks, sound brick, or asphalt paving blocks may be re-used. No permanent paving, other than granite, brick, or asphalt paving blocks, shall be placed within 30 days after the backfilling shall have been completed, except by order of the Engineer.

Sect. 16.26 *Cleaning Up:* Surplus pipe line material, tools, and temporary structures shall be removed by the Contractor, and all dirt, rubbish, and excess earth from excavations shall be hauled to a dump provided by the Contractor and the construction site shall be left clean, to the satisfaction of the Engineer.

Sect. 16.27 *Maintenance of Surfaces:* Following the certification of completion by the Engineer, the Contractor shall, unless otherwise required in Supplementary Specifications, maintain the surface of the unpaved trenches, adjacent curbs, sidewalks, gutters, shrubbery, fences, sod, and other surfaces disturbed for a period of 3 months thereafter; and shall maintain the repaved areas (if paved by Contractor) and adjacent curbs, gutters and sidewalks for one year after said certification. All material and labor required for the maintenance of the trenches and adjacent structures shall be supplied by the Contractor and the work shall be done in a manner satisfactory to the Engineer.

Section 17—Chlorination of Completed Pipe Line*

Before being placed in service, all new water distribution systems, or extensions to existing systems, or any valved section of such extension or any replacement in the existing water distribution system shall be chlorinated. See Addenda Sect. 2.4–2.45-a.

Any of the following methods of procedure (arranged in the order of preference) shall be followed, subject to the approval of the Engineer.

Liquid chlorine gas-water mixture Direct chlorine feed	Section 17.2
Calcium hypochlorite and water mixture Chlorinated lime and water mixture	Section 17.5
Dry Hypochlorite Dry chlorinated lime	Section 17.6

*Although the chlorination of reservoirs and elevated tanks is not within the scope of these specifications, they are sometimes used as the vehicle for supplying heavily chlorinated water to an entirely new distribution system in an advantageous and economical manner. This method of chlorination of water mains permits the preliminary flushing of all dirt and foreign matter from the new pipe system through hydrants or blow-off connections, which flushing is then followed with a dosage of chlorine introduced into the reservoir or tank and discharged into the pipe of the strength and for the retention time required in Section 17 of the specifications.

Sect. 17.1 *Preliminary Flushing:* (Not applicable to procedure of Section 17.6). Prior to chlorination, all dirt and foreign matter shall be removed by a thorough flushing through the hydrants, or by other approved means. Each valved section of newly laid pipe shall be flushed independently. This shall be done after the pressure test and may be done either before or after the trench shall have been backfilled.

Sect. 17.2 *Liquid Chlorine:* A chlorine gas-water mixture shall be applied by means of a solution-feed chlorinating device, or, if approved by the Engineer, the gas shall be fed directly from a chlorine cylinder equipped with proper devices for regulating the rate of flow and the effective diffusion of gas within the pipe. (Chlorination with the gas-water mixture is preferred to direct feed.)

Sect. 17.21 *Point of Application:* The preferable point of application of the chlorinating agent shall be at the beginning of the pipe line extension, or any valved section of it, and through a corporation stop inserted in the horizontal axis of the newly laid pipe. The water injector for delivering the gas-water mixture into the pipe shall be supplied from a tap on the pressure side of the gate valve controlling the flow into the pipe line extension. In a new system, application may be at the pumping station, or the elevated tank, or the standpipe, or the reservoir.

Sect. 17.22 *Rate of Application:* Water from the existing distribution system or other source of supply shall be controlled to flow very slowly into the newly laid pipe line during the application of chlorine. The rate of chlorine gas-water mixture flow shall be in such proportion to the rate of water entering the pipe that the chlorine dose applied to the water entering the newly laid pipe shall be at least 40 to 50 parts per million.

Sect. 17.23 *Back Pressure Prevented:* Back pressure, causing a reversal of flow in the pipe being treated, shall be prevented.

Sect. 17.24 *Retention Period:* Treated water shall be retained in the pipe long enough to destroy all non-spore-forming bacteria. This period shall be at least three hours and preferably longer as may be directed. After the chlorine treated water has been retained for the required time, the chlorine residual at pipe extremities and at other representative points shall be at least 5 parts per million.

Sect. 17.25 *Chlorinating Valves and Hydrants:* In the process of chlorinating newly laid water pipe, all valves or other appurte-

nances shall be operated while the pipe line is filled with the chlorinating agent.

Sect. 17.3 *Final Flushing and Test:* Following chlorination, all treated water shall be thoroughly flushed from the newly laid pipe line at its extremities until the replacement water throughout its length shall, upon test, both chemically and bacteriologically, be proven equal to the water quality served the public from the existing water supply system, and approved by the Public Health Authority having jurisdiction.*

Sect. 17.4 *Repetition of Procedure:* Should the initial treatment in the opinion of the Engineer, prove ineffective, the chlorination procedure shall be repeated until confirmed tests show that water sampled from the newly laid pipe conforms to the requirement of Section 17.3.

Sect. 17.5 *Calcium. Hypochlorite or Chlorinated Lime in Water:* On approval of the Engineer a mixture of either calcium hypochlorite or chlorinated lime of known chlorine content and water may be substituted as an alternative for liquid chlorine.

(a) Calcium Hypochlorite (comparable to commercial products known as "HTH," "Perchloron," and "Maxochlor") or,

(b) Chlorinated lime (frequently called chloride of lime and known to industry as bleaching powder) may be used.

Sect. 17.51 *Proportions of Calcium Hypochlorite or Chlorinated Lime and Water Mixtures:* A five per cent solution shall be prepared, consisting of five per cent of either powder to ninety-five per cent of water by weight.

Sect. 17.52 *Application:* This calcium hypochlorite or chlorinated lime and water mixture, first made into a paste and then thinned to a slurry, shall be injected or pumped into the newly laid pipe under conditions heretofore specified for Liquid Chlorine application, (Section 17.2—17.25) after preliminary flushing. (Section 17.1).

Sect. 17.53 *Approval:* Provisions for final flushing, testing, and approval under this alternative shall be the same as those described in Sections 17.3 and 17.4

Sect. 17.6 *Dry Calcium Hypochlorite or Chlorinated Lime:* On approval of the Engineer, dry calcium hypochlorite or chlorinated lime of the same chlorine content as that specified in Section 17.5

*All public water supplies should meet the quality standard required by the U. S. Treasury Department for water used on interstate carriers.

may be employed as an alternative procedure where facilities are not available for chlorinating in the manner heretofore specified.*

Sect. 17.61 *Dosage:* The dosage of calcium hypochlorite powder containing 70 per cent available chlorine shall be one pound for each 1,680 gallons of water pipe capacity treated; chlorine-yielding compounds other than calcium hypochlorite powder may, on approval of the Engineer, be used in amounts proportional to their available chlorine content. This dosage is equivalent to a treatment of 50 parts per million available chlorine. In like manner, one pound of calcium hypochlorite powder will treat 2,100 gallons of water to 40 parts per million chlorine.

Sect. 17.62 *Points of Application:* A predetermined dose shall be shaken into the suction well, the standpipe or elevated tank, or into the pipe at the first joint attached to the existing water pipe, and the dosage shall be repeated at frequent predetermined intervals, preferably at each pipe joint as the pipe laying progresses; or as may be directed by the Engineer.

Sect. 17.63 *Further Procedure:* When treated with dry calcium hypochlorite, or with dry chlorinated lime, the newly laid pipe shall be filled very slowly to avoid washing the powder to the extremity of the pipe line.

The period of retention, valve manipulation, and the final flushing and testing shall conform to the requirements of Section 17.24, 17.25, and 17.3 respectively.

Sect. 17.64 *Chlorination Repeated if Necessary:* In the event that the test in the opinion of the Engineer proves unsatisfactory, chlorination shall be repeated by employing acceptable alternative procedures until a satisfactory condition of the water within the pipe is established.

Sect. 17.65 *Procedure When Cutting Into Existing Pipe Lines:* Unless the Engineer shall direct otherwise, cuts made in existing pipe lines for the insertion of valves, fittings, repairs, or for any other purpose shall be chlorinated by shaking a quantity of the powder, predetermined by the Engineer, into the pipe on each side of the cut-in. After slowly filling the section and reversing the flow, the chlorinated water shall be retained for several hours, then flushed

* The practice of chlorinating newly laid pipe line extensions by introducing bleaching powder or calcum hypochlorite powder in dry form precludes preliminary flushing and therefore this practice is considered the least effective method of water main chlorination.

until no odor of chlorine can be detected in the waste water, or preferably until a check shall have been made for residual chlorine as provided in Section 17.24.

Sept. 17.7 *Resumption of Service:* After satisfactory chlorination by any of these alternative procedures, the consumers may be served from the newly laid pipe line or the service may be resumed on existing pipe lines.

Section 18—Definition of the Word "Engineer"

Whenever the word "Engineer" is used herein it shall be understood to refer to the Engineer acting for the Owner under the Contract, either in person or through properly authorized Inspectors or other agents limited to the particular duties entrusted to each. Likewise the words "authorized," "required," "approved," and words of similar import shall be understood to refer to the authorization, requirement, approval, etc., of the said Engineer.

ADDENDA TO TENTATIVE STANDARD SPECIFICATIONS

Section 2—Alternatives*

Sect. 2.01† *Materials Furnished by Owner:* The ________ Water Department (Owner) will furnish to the Contractor at its Yard or at such other points as may be designated by the Engineer, all pipe, fittings,‡ gate valves, hydrants, and other appurtenances and accessories to be incorporated in the pipe lines and made a permanent part thereof; excepting jointing material; masonry material; lumber for bracing trenches, shoring obstructions, blocking pipes if required, barricading, or bridging the work as it progresses; and excepting also all other materials and any stipulated in Sect. 2.10 incidental to the completion of the work.

Sect. 2.10† *Work to be Done by Contractor Including the Furnishing of all Material:* The Contractor shall furnish all pipe, fittings,‡ gate valves, hydrants, and other appurtenances and accessories to be incorporated in the pipe lines and made a permanent part thereof;

* Sections of the Addenda denoted by a plain numeral and also by a numeral followed by the letter "a" (Example Sect. 2.20 and Sect. 2.20a) neutralize each other. One only shall apply to the Contract.

† Both Sect. 2.01 and Sect. 2.10 should be used in modified form in special cases, as for instance when the Owner furnishes the pipe only.

‡ Eliminate any name of material to which this general statement does not apply.

including jointing material; masonry material; lumber for bracing trenches, shoring obstructions, blocking pipes if required, barricading and bridging the work as it progresses; and road re-surfacing unless otherwise stipulated. He shall furnish all other materials, labor, and facilities except as stipulated in Sect. 2.01, necessary to install the pipe and complete the work required to the satisfaction of the Engineer, in the manner herein specified.

All materials to be furnished by the Contractor shall be in accordance with the Supplementary Specifications hereto attached.

Sect. 2.20 *Blocking Pipe:* The Contractor will not be permitted to support pipe, fittings, or valves on blocking either temporarily or otherwise. The provisions of Sect. 9 do not apply.

Sect. 2.20a *Blocking Pipe:* The Contractor shall block pipe, fittings, and valves in the manner specified in Section 9.

Sect. 2.30 *Jointing Material:* In making pipe joints the Contractor shall employ the material and methods specified under the following alternative:

Sect. 2.31 *Lead:* Sections 10.4 to 10.44 inclusive.

Sect. 2.32 *Sulphur Compound:* Sections 10.5 to 10.55 inclusive.

Sect. 2.33 *Cement:* Sections 10.6 to 10.66 inclusive.

Sect. 2.40 *Chlorination of Pipe Lines Excluded:* Chlorination of pipe lines is not included in this Contract. The provisions of Sect. 17 do not apply.

Sect. 2.40a *Chlorination of Pipe Lines:* In chlorinating the pipe lines the Contractor will be required to follow the procedure specified under the following Sections.*

Sect. 2.41 *Liquid Chlorine Gas-Water Mixture:* Sections 17.2 to 17.4 inclusive.

Sect. 2.42 *Direct Chlorine Feed:* Sections 17.2 to 17.4, inclusive.

Sect. 2.43 *Calcium Hypochlorite and Water Mixture or Chlorinated Lime and Water Mixture:* Sections 17.5 to 17.53 inclusive.

Sect. 2.44 *Dry Hypochlorite or Dry Chlorinated Lime:* Sections 17.6 to 17.64 inclusive.

* Omit the sub-sections of Section 17 containing methods which will not be acceptable.

Sect. 2.45 *Chlorinating Equipment and Supplies:* These will be furnished by the Owner.

Sect. 2.45a *Chlorinating Equipment and Supplies:* These shall be furnished by the Contractor.

Sect. 2.50 *Water Used by Contractor:* Water for construction, testing, and chlorinating purposes will be furnished by the Owner without charge.

Sect. 2.50a *Water Used by Contractor:* Water for construction, testing, and chlorinating purposes will be furnished by the Owner at the prevailing rates.

Sect. 2.60 *Paving:* Permanent paving over trench cuts will be replaced by the Owner.

Sect. 2.60a *Paving:* Permanent paving over trench cuts shall be replaced by the Contractor in accordance with the Supplementary Specifications hereto attached.

* * * * *

Personnel of Sub-Committee 7-D, Laying Cast-Iron Pipe

W. C. Mabee. Indianapolis, Ind.
Thomas J. Skinker. St. Louis, Mo.
Clinton L. Bogert. New York, N. Y.
Samuel E. Killam. Boston, Mass.
William M. Rapp. Atlanta, Ga.
J. B. Winder. Dallas, Texas
Frank Y. Dorrance. Montreal, Can.
B. A. Poole. Indianapolis, Ind.
William W. Hurlbut. Los Angeles, Cal.
Ralph W. Reynolds. W. Palm Beach, Fla.
George W. Pracy. San Francisco, Calif.
Eugene T. Cranch. New Rochelle, N. Y.
George T. Routlege. Toronto, Canada
H. Lloyd Nelson. Pittsburgh, Pa.

Submitted to the Committee on Water Works Practice via Committee 7 on December 30, 1937

By W. C. Mabee, *Chairman.*

THE PHYSIOLOGICAL ASPECTS OF MINERAL SALTS IN PUBLIC WATER SUPPLIES

By Sidney S. Negus

Very few inorganic substances, in the concentration found in public water supplies in most sections of the country, have been really proven, by scientific data, to affect the public health. Some substances may affect the odor, color, taste and turbidity, but practically all of these are harmless physiologically even in concentrations sufficient to give high odor intensity, high color and turbidity, and oftentimes disagreeable tastes (1). These characteristics, especially odor and taste, however, may affect some persons psychologically to the extent that they may develop physiological reactions. The odor factor is so important that professional water smellers and special testing devices have come into the field (Fair and Wells osmoscope). Methods for the procedure of odor testing are being standardized (2). Most water consumers would turn down water triply distilled and condensed through block tin coils with the criticism that the water tasted "flat." Conductivity water is not considered palatable because people have not been accustomed to drinking strictly pure water. There is obviously much difference between a pure water and a physiologically safe one. It may be a simpler matter to define safe water than pure water. No person knows definitely what pure water is. It certainly is not H_2O in the liquid phase. Defining a physiologically safe water is not an easy matter, however, due to the fact that experimental data are so conflicting.

For esthetic reasons, a drinking water must be as free of taste, color, odor and turbidity as possible, even though the substances causing them are in themselves harmless, and even though the esthetic quality of a water may change greatly without much appreciable chemical change. In other words, water chemists and engineers must, of necessity, be good psychologists as well as water purification

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A paper presented before the meeting of the Virginia Section at Richmond in November 1937 by Sidney S. Negus, Professor of Biochemistry, Medical College of Virginia, Richmond, Virginia.

experts. Keeping water purification plants spotless and as free of odor as possible, beautifully landscaping them, insisting on personnel of neat appearance and encouragement of visitation on the part of the consuming public may not affect in the slightest degree the purity of the finished water, but such things will go a long way in creating good-will towards the public water supply in any community.

Along esthetic lines further, the following is a most important consideration. It is agreed by health authorities that human beings, in general, do not drink enough water (3). One of the most important problems of water works men is to produce a water which the public will want to drink freely. A drinking water with enough free chlorine in it to give it a pronounced chlorinous taste will never harm anyone, but consumers may take it rather than nothing or else not drink it at all. As a general rule, a non-palatable water may do more harm indirectly from a physiological standpoint, due to people not drinking it, than all the chemicals in the water put together may do directly. Therefore, odor, color, taste and turbidity are indirectly very important considerations physiologically.

GENERAL CONSIDERATIONS

The presence of inorganic material in water is of more importance to an industrial water chemist than to a sanitarian. On the other hand, the bacteriology of potable water is very important, whereas not so much so in the case of an industrial water. The physiological effects of bacteria in a water supply are very well defined. No reference to them will be made in this paper.

The data on physiological tolerance to inorganic impurities in potable water are widely spread throughout the literature on the subject, and are very conflicting, and to quite an extent, scientifically shabby. To start with, it must be borne in mind that only general statements can be made concerning these physiological effects. The problem is very difficult to investigate, hence reliable information based on exact laboratory experimental data is surprisingly lacking. The limits for chemical constituents have been based largely on the experiences of observers and investigators over considerable periods of time. Much that is known concerning physiological effects has been obtained by the actual use of waters by consumers rather than by exact laboratory studies. Only approximate data can be obtained, since human beings are not alike physiologically and idiosyncracies come into the picture. Then, susceptibility varies with

different ages, sex, physical conditions, and so forth. Besides, the effects of small traces of many substances on the body's chemistry are not at all well understood, even by specialists.

Almost every year, another one of the ninety-two elements is added to the list of those having importance physiologically, zinc being one of the most recent. Further, the physiological effect of simple metallic ions may be entirely different from that of complex ions containing the same element. For example, there is no reason to believe that zinc ions and zincate ions have the same effect physiologically. There are so many possibilities and so many variables that it is easily understood why there is such a paucity of reliable data on the subject.

THE TREASURY STANDARD

It is not well understood, even by some water works men, that pages 24, 25 and 26 of the U. S. Treasury Department Water Standards for Drinking and Culinary Water Supplied by Common Carriers in Interstate Commerce, June 20, 1925, are not, strictly speaking, part of the standards, but an appendix (4). The *suggestion*, so far as physiological and chemical characteristics of a satisfactory water are concerned, reads, "The water *should* be clear, colorless, odorless, and pleasant to taste, and *should not* contain an excessive amount of soluble mineral substances nor of any chemicals employed in treatment." Only in the case of lead, copper and zinc are the words "shall not exceed" used. "Should not exceed" are the words used in referring to sulfate, magnesium, total solids, chlorides, iron, caustic alkalinity, odor and taste of free chlorine and carbonates.

Domestic water supplies, which meet the suggested limits and the recommended ones for copper and zinc, are overly safe physiologically since the limits in every case are set quite low. Lead ions, however, are in a different class. It is definitely known that there is a great difference in physiological effects between intermittent dosage and long continued dosage of the salts of heavy metals. Applying limits for water on interstate carriers to domestic waters, which are consumed several times each day over extended periods of residence, is certainly "playing safe," and presumably that is the use the U. S. Public Health Service officials and their advisory committee anticipated would be made of the standards, when the suggestions and recommendations were published. This was their only alternative considering the absence of reliable data on the subject in 1925. It

seems probable that in the light of more recent knowledge the standards will be revised as to copper, zinc, caustic alkalinity, fluoride and possibly (?) barium and selenium. The danger of barium and selenium ions in a public water supply is so remote that it would be going rather far including them in drinking water standards.

All metals dissolve in water. In discussing the metallic ions commonly found in water supplies, only the simple ions will be considered. No attempt will be made to differentiate between physiological effects of metallic ions in association with various acid radicals.

COPPER

Copper, the first substance to be considered, has, within the past ten years, been found to be of importance as a supplement to iron for hemoglobin regeneration (5). The element is known to be an essential constituent of tissue cells. Prolonged heavy exposure to copper ions produces body damage. The physiology concerned is controversial (6). The traces left in potable water, after purification and distribution, however, are certainly in no way harmful to normal individuals. 0.2 p.p.m. of copper, in drinking water supplied by common carriers in interstate commerce, has been set by the U. S. Public Health Service as the limit above which a water may be rejected (4). A person drinking two quarts of water a day (the average intake) with this much copper in it would be getting approximately 0.4 mg. of the substance. The body requires at least 2 mgs. a day, so 0.2 p.p.m. of copper is probably helpful, certainly not harmful. The increased use of copper and brass pipes in water distribution and the use of copper sulfate in the purification process as an algaecide, however, make it necessary for one to be on the look-out (in soft waters especially) for excess copper in a water supply. The source of copper from the distribution system is far greater than from the copper sulfate used at the purification plant, especially if the carbon dioxide content of the water increases during distribution and if the water is of low bicarbonate alkalinity.

Chloramines in finished water in the traces they occur, if at all, have never been proven to be physiologically objectionable. Of course, chlorophenols may produce ill tasting and smelling waters, but the right use of ammonia will prevent the formation of these compounds and the chlorinous tastes as well. The suggestion by Major Harold in England (7) and in this country by Griffin (8) as to the continuous use of chlorine and ammonia with copper sulfate

to keep available copper from precipitating out as copper carbonate and to secure more prolonged algaecidal action during the purification process does not increase the copper hazard as far as is known. If any complex copper compounds, such as the so-called "cuprichloramine" (which is considered algaecidal) result from this treatment, they may mean very slightly more copper in the water from the distribution system. Copper ions and copper tied up in complex ions may have altogether different physiological effects. Recommending that copper should not be present in potable water over 0.2 p.p.m. has reference to copper ions. No work has been done on the physiological effects of copper tied up in complex ions. All that can be said is that, from consumer experience, in the few places where the newly suggested continuous ammonia-chlorine-copper sulfate treatment has been used no public health problem has arisen. The rather general and unfounded fear of copper in public water supplies plus physical difficulties in making changes have probably kept operators from trying this treatment. It may have advantages from an operative standpoint for some plants.

Practically everything is poisonous and nothing is poisonous if used correctly. This applies to copper ions. Instances may be cited where high ionic concentration of copper has produced body damage while, on the other hand, traces of copper ions are definitely known to be physiologically necessary (9). The time may come when it will be considered by public health officials to be advantageous biochemically to have traces of copper in public water supplies although they as yet have never come to this even with iodine. Hamilton writes (10), "One must have supreme faith in the teachings of the homeopathic school of medicine, to be able to recognize the value of minerals in drinking water." A U. S. patent has just been granted (11), however, for incorporating iron in milk and McGhee (12) is investigating the physiological values of copper and iron metallized milk in the diets of individuals while others are concerned with the use of copper and iron salts in therapy (13, 14, 15). A number of biochemists and physiologists claim that the old time method of cooking in copper and iron vessels was of definite physiological importance.

No case of copper poisoning from a purified water supply has ever been definitely proven. Schnetz (16) has fed daily as high as 20 mgs. of copper as sulfate in the treatment of diabetes without any apparent harmful effects. Schneider (17) claims that as high

as 5 p.p.m. of copper in a potable water should be admissible and that a greater amount than this affects the taste of the water for some people although other investigators claim that less than this amount will make the water unpalatable. Froboese states (18), "The lowest concentration of copper in water at which it can normally be tasted is 1.5 mg. per liter." It is necessary for about 30 p.p.m. of copper ions to be present in water before the staining of white plumbing fixtures will begin, so obviously this check is of little value as compared with the sense of taste. So far as all reports of experience and research results are concerned, it has certainly been well proven that a copper limit of 0.2 p.p.m. (about half the amount present in raw cow's milk) is much lower than necessary, even for laundering. Five times this amount or 1 p.p.m. would still be "playing safe."

ALUMINIUM

The aluminium ions which get into a distributed purified water supply, due largely to the use of aluminium sulfate in treatment, have unnecessarily disturbed many communities in the past. Fortunately this aluminium scare is now out of the minds of consumers. Flinn and Inouye (19) and others have proven that food cooked in aluminium utensils have never given evidence of harming anyone. Certainly aluminium ions in the concentration in which they may occur in a purified water supply constitute no public health problem.

ARSENIC

The little arsenic getting into a purified potable water supply is neglible. A method of determination for it is not even listed in Standard Methods of Water Analysis (20), neither is this element among those having a limit suggested in U. S. Treasury Department. Drinking Water Standards* (4). Yet every so often somebody starts worrying about arsenic! Some purification plants manufacture their own coagulants. Using arsenic-free sulfuric acid in the process sounds good esthetically, but means nothing scientifically. It is like reporting analytical data to the fourth decimal

* England has a limit of 1/100 grain per Imperial gallon, which is 0.2 p.p.m. The U. S. Food and Drug Administration specifies the tolerance for arsenic as arsenic trioxide as 1.43 p.p.m. Considering the proportion of food ingested to that of water, the Food and Drug Administration limit for food is really stricter than the English one for drinking water.

place when the method is only accurate to the second. The amount of arsenic getting into the water supply from galvanized iron pipe is neglible since practically no arsenic can be found in such piping (21).

The English limit of 0.2 p.p.m. arsenic is very seldom met with in a purified water. As indicated before, 1 p.p.m. of a substance in a water ingested to the extent of two quarts daily means that the person gets approximately 2 mgs. of the substance concerned. Two quarts of water with 0.2 p.p.m. of arsenic would be equivalent to 0.4 mg. of arsenic daily. This amount has never been proven as harmful to a person. There are reported in the literature cases of arsenical poisoning traced directly to water from wells in regions where the limestone contains ferrous arsenate (22), and where much arsenic spraying is done, but I know of no report in the literature of arsenical poisoning from a purified potable water.

LEAD

Lead ions seem to have a bad reputation, although some of it is not deserved when it comes to the *traces* found in most purified water supplies. If the very small amounts of lead, which persons ingest by drinking water and eating food, were as harmful as some people believe them to be, there would be many more cases of lead poisoning than are known to occur. The principal reasons why this element is in such bad repute are the following:

1. The lead poisoning cases traced directly to public soft water supplies in New England (23), Germany (24), France (25) and England (26, 27, 28).
2. The difficulty of determing lead accurately in the amounts the element occurs in potable waters (29).
3. Plumbism cases traced directly to streams and wells near heavily lead arsenate sprayed regions.
4. The rather wide-spread but erroneous idea that lead is steadily accumulated in the body, none being excreted.
5. The publicity given, both in the press and in scientific literature, to plumbism cases due to inhalation (not ingestion) of high concentrations of lead ions, as in the paint industry.
6. Published articles by some able chemists whose conclusions in the field of toxicology are unsupported by physiological evidence.

Based largely upon these facts and not upon unquestionable scientific data, 0.1 p.p.m. of lead is the limit above which the U. S.

Public Health Service may reject a potable water on common carriers in interstate commerce (4).* This is the strictest specification of all the inorganic ions listed. There is no question but that it should be strict, since lead ions are more poisonous than any of the other common ones occurring in a water supply, such as copper and zinc. Perhaps it is best to "lean over backwards" with such a low limit, even though data published since 1925 indicate that it might be raised slightly (e.g., work of Howitt and Cowgill (29)).

A present day adequately purified water contains only minute amounts of lead ions (63). Lead in a water supply may come from the distribution system, since lead pipes are often used to connect mains with domestic lines. An alkaline, CO_2-free water upon leaving a purification plant is negligibly aggressive to lead. Before it reaches the consumer, its aggressiveness may be increased due to acid-forming organisms in remote parts of the distribution system. Oxygen content, the relation between free and combined CO_2 and whether or not the water is a ground or surface one are of primary importance in plumbo-solvency. If an aggressive water is allowed to stand too long in contact with lead, some lead ions will get into the water supply. Obviously, depending upon the nature of the water supply, some communities should not use lead piping. Public supplies of purified soft water in the United States at large, however, are the exceptions rather than the rule. New Bedford, Mass., has a ruling that those in charge of collecting the water shall have charge also of the distribution system. Under such an arrangement water works men become definitely responsible for the water which reaches the consumer, whereas in most communities the water works engineer gets blamed for conditions out of his control. Those in charge of collecting or purifying a water know better than anyone else when lead piping in a distribution system is indicated and when its use may even be advantageous. Of course, a home, factory or office building where the drinking water is piped by lead is potentially dangerous for those drinking the water, especially if the water is soft, not buffered, and has had a chance to stand in the

* The Federal Food and Drug Administration's tolerance for lead in foods is 2.57 p.p.m. It is reasonable to assume that a person might take in a day a quarter of a pound of food containing 2.57 p.p.m. of lead. This would mean ingesting about 0.28 mg. of lead. Drinking two kilograms of water (approximately two quarts) containing 0.1 p.p.m. would give 0.20 mg. of lead so the limits on food and water are quite comparable.

pipes for any length of time. Quam and Klein (30) have shown that samples of water containing 0.025 mg. of lead per liter (hardness 21 and alkalinity 10), after exposure to lead pipes for seven days, have increased in lead content to as high as 1.465 mg. per liter. These authors point out that it is entirely possible that the portion of water standing in lead pipe, even if only five feet in length as a connecting line between the main and domestic line, may just reach the faucet in time to empty into a drinking glass. They found new lead pipes more potentially dangerous than old ones. With such a situation as these investigators dealt, however, one would seldom meet. Kehoe, Thamann and Cholak write (31), "The possibility of significant contamination of city water supplies from extensive use of leaden pipe has been emphasized frequently. This is a potentially important matter wherever lead pipe is employed to distribute water, but in many cities of the United States it has little practical significance, because of the limited use of lead in pipe lines. We have recently noted an unexpected means for the introduction of considerable amounts of lead into water in that pipe joints are luted with materials of high lead content which continue to yield lead to to the water of new buildings for some time. In such a building, we found lead in the water in concentrations varying from 0.37 to 0.92 mg. per liter, after water had been permitted to stand in the pipes for variable periods of time; after all the taps had been allowed to run freely for 15 minutes, samples of the water showed only 0.03 mg. of lead per liter, and after an hour of running, lead could not be detected."

Kehoe, Thamann and Cholak (31, 32) have cleared up the question very thoroughly concerning the normal absorption and excretion of lead. They have splendid data to show that ingestion of lead ions in normal amounts does not result in steady accumulation of lead in the body. They write "Apparently an equilibrium is reached after a time, so that a substantially constant concentration of lead remains in the tissues, and lead output becomes equivalent to lead intake." The word "apparently" makes this statement a hypothetical one and not one of fact. This hypothesis, if it can be substantiated definitely as a scientific fact, is certainly at variance from the impression held by most people that the minute quantity of lead ions ingested are withheld by the body until the time when storage is high enough to bring about an attack of lead poisoning. This erroneous and popular view gives the body no credit for being

able to eliminate small amounts of lead without injury (33). Spectrographic methods for accurately determining small amounts of lead have made it possible to prove that the element is a virtually constant constituent of human tissues, a claim made by Devergie in 1838 (34). Whether its presence is accidental or functional is not known. It is not unreasonable, especially after the recent work of Elvehjem and Hart (35) upon the physiological need for zinc, to predict that lead may be present in the body for functional purposes.

The lead problem in public water supplies is still a controversial one. In such a paper as this, further discussion of it would be going too far afield. Suffice it to conclude with these statements:

1. Even water well corrected at the purification plant should not be allowed to stand too long in contact with lead.

2. Water works engineers should check water reaching consumers for lead content. The presence of 0.1 p.p.m. of lead should call for investigation, even though this amount may be a low human tolerance limit for most people.

3. Lead piping should be eliminated in those distribution systems where the water is aggressively soft, swampy, or peaty in origin and has been untreated. It should also be eliminated for carrying drinking water which does not contain substances which will form protective coatings on lead surfaces.

Until more is definitely known about the physiological effects of traces of lead ions, public health officials obviously must be sure that their recommendations are on the safe side.

HARD WATERS

One quite often is told by water supply consumer critics that due to the calcium and magnesium content of drinking water, all of our alimentary canals are gradually becoming coated with scale like a boiler, all of which means nothing. Hard waters have been and are still blamed, even by a few physicians, for almost every disease and especially kidney trouble, arteriosclerosis, constipation, gall stones and rheumatism! Hard waters have been exonerated many times by investigators, in 1911 by Lewis (36), in 1924 by Chase (37), again in 1925 by Myers (38) and White (39), and so on, both by the study of mortality statistics and experimental research. The evidence is rather convincing and it remains for reliable investigators to disprove. I have been unable to find any reliable published paper which definitely indicates that hard water, such as supplied by the

majority of U. S. public water works away from the Atlantic Coast, is of any harm physiologically. Correcting the pH of the water with lime is doing the public a favor—since the one element perhaps most lacking in the American dietary is calcium; and, an insoluble calcium salt coating of distribution pipes is sometimes desirable in preventing corrosion.

The human body requires approximately 0.7 to 1 gram of calcium a day. To be utilized effectually, factors controlling its absorption must be adequate (40). Sherman (41) and others state that the calcium in drinking water supplements that taken in food as far as body requirements for the element is concerned. This means that the comparatively little inorganically combined calcium absorbed from drinking water is helpful and certainly not harmful.

Considerable amounts of calcium salts affect the palatability of water, but that is a matter of individual tastes. As a general rule, excepting for very few of the metallic ions, the taste factor will prevent consumers and even animals from harming themselves physiologically from water ingested. There still seems to be no good scientific reason to add calcium to the list of ions limited in drinking water by the 1925 U. S. Public Health Standards.

CAUSTIC ALKALINITY

One of the few recommendations of the U. S. Public Health Service Standards for interstate water supply written in italics is that "water should contain no caustic alkalinity" (4). This specification, from a health standpoint, has no defense. It is more a requirement of good filtration plant operation since if softening is involved in the treatment and much caustic alkalinity is concerned, there is likely to be an extensive deposit of calcium carbonate in the pipe lines. Concerning this recommendation from a physiological viewpoint, a committee of the division of Water, Sewage and Sanitation Chemistry, American Chemical Society has reported in part as follows: "(42) . . . Investigation by your committee develops that there are a number of locations in the United States where waters containing caustic alkalinity have been furnished and used for drinking and domestic purposes for as long as 16 years with no apparent adverse physiological effects. Search by your committee of available literature develops no reference to permissible amounts of caustic alkalinity in drinking water other than the mere statement contained in this report. There appear to have been no facts or research which would substantiate possible detrimental results from

using waters containing small amounts of caustic alkalinity. . . . It is the recommendation of your committee that this subject be referred to the Council with the suggestion that it be assigned to the Physiological Chemistry Section of the Division of Biological Chemistry, or the Division of Medicinal Chemistry, for further study, report, and recommendation."

This report was approved by the Division of Water, Sewage, and Sanitation Chemistry, September 11, 1934, with the added request that the matter be also referred to the American Medical Association. Nothing has come of it since that time. Hale writes in September, 1935 (43), "It seems unlikely that a small excess of lime hydrate alkalinity in drinking water would have any deleterious effect on health. It might have effect upon taste, although in these experiments, it required the highest quantity, 100 p.p.m., to cause a distinct limelike effect. The dividing line probably lies between 50 and 100 p.p.m."

Of course, the greatest variable one encounters in passing from one region to another is water. For this reason, it is often claimed that changing from one water supply to another brings about intestinal changes in the persons concerned due to differences in the substances dissolved in the waters. There is no question but that such intestinal disturbances occur but they are probably due to an adjustment of the intestinal tract and metabolic processes to new conditions, principally pH, rather than to the fact that the changed water supply is unhealthful.

According to the Treasury Standard, magnesium should not exceed 100 p.p.m. (4). Like calcium ions, magnesium ions in public water supplies are definitely of no public health concern. The magnesium salts will affect the taste of the water more than calcium ones. Obviously, magnesium sulfate concentration should not be too high in a potable water. If a consumer finds a potable water palatable, he surely will not be ingesting too much magnesium. This element is now known to be essential to human body function, approximately 0.34 gram being required per person per day (41). Drinking two quarts per day of the hard water of the middle west will not give this amount.

IRON

Iron salts, ferric and ferrous, in drinking water are harmless physiologically. The limit of 0.3 p.p.m. (4) is rather for taste and color considerations than for physiological reasons. One requires at

least 5 or 6 mgs. of iron a day. Inorganically combined iron as present in drinking water can be absorbed and utilized. From two quarts of water with 0.3 p.p.m., one would obtain about 0.6 mg. of iron, so the limit on iron is very low from a biochemical standpoint. Water leaving a purification plant with 0.3 p.p.m. could not pick up enough iron from the distribution system to make the element of any concern from a health standpoint. Enough iron present to make the water objectionable to a laundry is not enough to be of importance to public health officials. There is a reason for keeping iron in a potable water low, but it is certainly not a physiological one.

SODIUM AND POTASSIUM

Sodium and potassium, found in all purified waters, are of no significance biochemically in the amounts present. Sodium is the least toxic of the cations employed in therapeutics.

ZINC

The Public Health Service's limit of 5 p.p.m. (4) of zinc in drinking water presumably was set because of consumer experiences which, in recent times, have been proven by scientific investigations as wrongly interpreted.

Heller and Burke (44) report as follows: "Zinc added to a normal ration either in the form of pure zinc dust, zinc oxide, or certain zinc salts, in amounts as great as ever found in contaminated foods did not interfere with growth, reproduction, and normal functions of the rat through three generations. No pathological conditions were found in the organs of rats fed the rations used in this experiment. The total ash content of the organs studied showed no perceptible increase."

Drinker, Thompson and Marsh (45) report that organic and inorganic zinc salts fed to rats in doses from 2 to 36 mgs. of zinc daily for long periods of time had no significant effect upon the health of the parents, upon fertility nor upon the health and early growth of the offspring and that zinc even in large doses did not result in storage of zinc in the animal in amounts above the normal.

Bartow and Weigle (21) have made an effort to determine the effect of inorganic zinc salts administered to animals in drinking water. They fed rats for 40 days as high as 1000 p.p.m. and report as follows: "The rats ate less, and gained less. These results might

be due to the astringent metallic taste of the solutions containing a high percentage of zinc sulfate. All the rats were apparently healthy at the close of the experiments. Those on 1000 p.p.m. of zinc solution were noticeably irritable and easily startled on hot days, but on cool days were apparently normal."

Drinker and Fairhall write (46) "When the source of zinc contaminating water is galvanized pipe—and this is the most common situation with which we deal—the zinc compounds in the water will be a mixture of oxide, hydroxide, and carbonate, the latter predominating. If present to an amount of 30 mg. of zinc per liter, or 30 p.p.m., zinc carbonate will cause appreciable milkiness in the water, and many persons will complain of an astringent taste. While there is no reason to consider this harmful, it is doubtful whether any community would tolerate it without incessant complaint. Both taste and appearance act to prevent zinc in its most common form from being a persistent contaminant of water supplies even in amounts which are harmless." Also "This limit" (that is 5 p.p.m. of zinc) "has been applied freely to many conditions in which zinc is ingested. Since the zinc ion is not of itself poisonous, and many times 5 p.p.m. may be taken without harmful effects, it is suggested that this limit, which gives a relatively innocuous metal an undeserved reputation for toxicity, be increased or done away with altogether. Foods or beverages, with the exception of simple or chlorinated drinking water, should not be stored in zinc-lined or galvanized containers." Relatively high zinc ion content waters should not be used in making acid drinks, such as lemonade, due to the formation of poisonous organically combined zinc salts, e.g., zinc citrate.

Lothian and Ward (47) and Anderson, Reinhard and Hammel (48) have shown that chlorinated drinking water is not abnormally corrosive to zinc, whereas distilled water is. The last three investigators have partially reviewed the literature on the physiological effects of zinc ions in water supplies and report consumer experience to as high as 40.76 p.p.m. without any apparent harmful effects. These authors believe that waters containing up to 40 p.p.m. (high enough to impart a taste) are safe for human consumption. They point out that "apparently the effect of zinc on the human system is governed to a considerable extent by the acid radical with which it is associated. Thus zinc chloride is regarded as the most caustic of the common zinc salts. Zinc sulfate is somewhat caustic, but to much lesser degree than the chloride. Zinc oxide and zinc

carbonate are not considered corrosive." Drinker and Fairhall previously had arranged the zinc salts in the order of their irritability or causticity as follows: chloride, sulfate, acetate, lactate, tartrate and malate.

Obviously, with scientific data so over-balancing the hearsay, and taking into consideration the recent work of Elvehjem and Hart (35, 49) upon the physiological need for zinc, the new limit to be set for this element in the near future by the U. S. Public Health Service should be much higher than 5 p.p.m. especially since the occurrence of excessive amounts of zinc ions in public water supplies is rare. More good scientific data like this for zinc are needed for some of the other ions.

MINOR IONS

Selenium, boron, manganese, radium, silver and barium present in water supplies in sufficient concentrations to be of public health concern constitute highly sectional problems and will not be discussed at length in this paper.

Highly seleniferous forage has killed cattle but "in no case, with the possible exception of drainage water from an irrigation ditch in Colorado, has a sufficient selenium content been found to cause immediate death." The assignment of water as the cause of animal disease or death in seleniferous areas is quite common. However, Miller and Byers report (50) "It seems, however, to be usually, or always, a secondary cause." The selenium health hazard is being studied thoroughly by M. I. Smith and others (51, 52, 53, 54, 55). The presence of selenium ions in a public water supply may be a health hazard in a few sections of the country but it is a rather remote possibility.

Boron ions are of great importance to plant life. An excess or deficiency of boron in water used by plants has marked effects. The element, however, does not offer a public water supply problem as far as is known at present. Boron ions in concentration high enough to affect plant growth will have no adverse physiological effect as far as present knowledge of the problem is concerned (56, 57).

Manganese like its near relative, iron, has to be removed from potable water for reasons other than physiological ones. There is no public health danger from this element which in recent years has come to be considered essential to normal body function (58).

There is no case reported in the literature of radium poisoning by drinking waters (59). This is a nostrum problem only.

Little is known about the biochemistry of silver (60, 61). Due to the use of silver in a water sterilization process, consideration of the physiological effects of silver ions has come into the picture. Besides, consideration is being given to the possibility of silver ions removing available iodide ions from water supplies, silver iodide being insoluble. The latter possibility also applies to barium. In Switzerland, where there is an appreciable amount of barium in drinking waters, endemic goiter is of a much more severe type than in this country. Boissevain and Drea (62), however, have shown that there is no relationship between incidence of goiter and the silver and barium content of water supplies. The physiological effects of both of these ions, when present in water constantly used, are unknown at the present time. All these elements mentioned, however, may come into the picture in the future as fluorine has in the last few years, perhaps making it necessary to have spectrometric equipment in water purification plant laboratories (63).

No research work has been done on the tolerance of the human body to hexavalent chromium. At least one proprietary preparation which is being sold to add to water supplies for the purpose of preventing corrosion of piping produces, when used as directed, a concentration of 0.31 p.p.m. sodium chromate or 0.1 p.p.m. chromium. Since nobody knows the physiological action of small amounts of hexavalent chromium, it would seem judicious to study the matter before approving addition of such ions to a public water supply. For all anyone at present knows, amounts of chromium as low as 0.1 p.p.m. may be physiologically harmful just as fluorine is known to be in that amount.

FLUORIDES

Measurable physiological effects have been definitely noted from too much fluoride in water supplies. Chalky white patches upon the surface of the teeth (so-called "mottled enamel") have in many cases been definitely traced to an excess of fluoride in drinking water. In 1901, the disease was first reported in Italy by Dr. J. M. Eager of the U. S. Public Health Service (64). In 1907, papers about the disease began appearing in this country. As far back as 1918 (65), it was known that drinking water was somehow connected with mottled enamel, but not until 1931 was fluoride found to be the cause

(66). The fluoride problem is fortunately a sectional one, but more widespread than generally thought, especially as concerns well waters. It must be kept in mind that public water supplies are not the only sources for fluoride and that all dental fluorosis cannot be blamed upon drinking water.

Many reports in the literature (67 to 91) and one very recently by Dean and Elvove (92) present evidence to prove that amounts of fluoride not exceeding 1 p.p.m. in drinking water are of no public concern.* From all the investigative work which has been done on fluoride, it seems desirable that the new revision of Appendix IV of the U. S. Public Health Service Drinking Water Standards list the limit of fluoride (as F) as 1 p.p.m. It is unfortunate that the physiological aspects of all the chemical elements appearing in public water supplies have not been studied as comprehensively as fluorides. The effects of salts of this particular element on the human body, however, are easier to follow, the teeth acting as indicators.

IODIDES

Iodine in drinking water is a sectional problem and does not call for extended discussion in this paper. The physiological effects of complete lack of this element are well known. Very little iodine is needed per day by an individual. 10 parts of iodide per billion of drinking water is regarded as an adequate supply to protect against goiter (41). In most sections of the country, a person gets much more than the amount needed from food and water ingested, so no problem is presented by iodine excepting in goiter regions. Iodization of public water supplies has been done in some places, notably, Rochester, N. Y. (93), but it is not a procedure advocated by medical authorities because of sensitivity to the element in the case of some individuals. The use of iodized table salt in goiter zones is more easily controllable than an iodized public water supply. Many physicians are even averse to the general use of table salt containing iodides, preferring instead iodide medication to the comparatively few who may need it. Certainly iodized table salt is over-used in this country. I know of no case where harmful physiological effects resulted from iodides in a purified water to which no iodide had been added.

* The Federal Food and Drug Administration tolerance for fluorine in foods is 1.45 p.p.m., a limit much stricter than 1 p.p.m. suggested for drinking water. The reason for this stricter limit for foods has been given in a foot-note on page 249.

CHLORINE

Less than 1 p.p.m. of residual free chlorine remains in potable water after good purification and distribution (94). Free chlorine is a very reactive element. Even if it leaves the source of supply higher than 1 p.p.m., it is cut down in distribution, so there is no danger physiologically from residual chlorine. Chlorine introduces a taste problem and not a physiological one. Water works men should keep the free chlorine content below 1 p.p.m. for the health of gold-fish, if for no better reason. Certainly no demonstrable physiological effect has ever been reported from ingesting a purified water high enough in free chlorine to give a distinct chlorinous taste.

CHLORIDES

Chlorides to the extent of 250 p.p.m. are allowed in drinking water (4), and are of no harmful importance physiologically to normal individuals, although they do affect taste. Seldom do the chlorides ever approach this figure, except in certain sections. Some water supplies in the country contain greater than 500 p.p.m. chlorides with no apparent harmful results to consumers. Most people cannot taste sodium chloride when it is present to the extent of 350 p.p.m. Of course, there is quite a fluctuation in the thresholds of taste sensation, due to various factors acting on the nervous system. With repeated practice in the determination of tastes, however, a considerably keen taste sensitivity can be developed (95).

SULFATES, CARBONATES AND TOTAL SOLIDS

The U. S. Treasury Department Drinking Water Standards set an upper limit for sulfates of 250 p.p.m. (4). This figure was not included for physiological reasons, since the biochemical effects of sulfates in comparatively low concentrations are not known. The cathartic effect of magnesium and sodium sulfate in relatively large doses is well recognized, but what their effects are in real small quantities is very difficult to determine. A water satisfactory to industry in the way of sulfate content will certainly be harmless physiologically as far as anyone knows at the present time.

Carbonates need not be brought into the discussion since they have never been proven physiologically harmful in the amounts they occur in a purified water. The limit of 50 p.p.m. (4), calculated as normal calcium carbonate, is much too strict from physiological considerations.

1000 p.p.m. for total solids is the limit recommended by the Treasury Standards (4). Taste is concerned here—depending upon the salts which make up the 1000 p.p.m. Some western waters contain total solids higher in amount than this without any apparent physiological effects resulting. The average potable water carries from 50 to 500 p.p.m. of dissolved solids. Travelling from a community with a water supply of high total solid content to one having less solids dissolved means an adjustment for a consumer physiologically, but this does not mean that either of the waters are physiologically harmful. 1000 parts of total solids to a million of water is high enough concentration to produce a taste to most people no matter what the combination of salts may be. From a taste standpoint, therefore, and not from a physiological one, this limit is one which might be justifiably lowered.

PYRIDINE FROM AMMONIUM SALTS

This paper has nothing to do with organic impurities in a public water supply. In closing, however, I would like to include one organic substance about which questions are often asked. Some purification plants for the purpose of economy, are using a by-product ammonium sulfate. The ammonia, being of coke oven origin, may contain pyridine. Pyridine is not especially toxic, although word has got around among some water works men that it is! Solutions as high as 10 per cent have been used therapeutically in treatment of upper respiratory afflictions. The little pyridine which gets into a water supply, due to the use of by-product ammonium sulfate, is of no importance physiologically. Heller and Pursell have reported (96) that a substance considered as toxic as phenol may be very inocuous even when in comparatively high concentration in drinking water. Working with rats, they report, "It is surprising that waters containing 5000 to 8000 p.p.m. apparently do not interfere with growth, reproduction and lactation—and even 12000 p.p.m. may be tolerated." If this be true, it will serve as one of the best examples to show that jumping at conclusions without the support of scientific data is very risky.

SUMMARY

1. Very few inorganic substances, in the concentrations found in public water supplies in most sections of the country, have been really proven by scientific data to affect the public health.

2. As a general rule, a non-palatable water may do more harm indirectly from a physiological standpoint, due to people not drinking it, than all the chemicals in the water put together. Besides, a non-palatable water may cause consumers to resort to other waters which are palatable but unsafe.

3. As a general rule, excepting for a very few of the ions such as lead and fluorine, the taste factor will prevent consumers from harming themselves physiologically from water ingested.

4. False conclusions deduced from consumer experience rather than from sound scientific data, have been considered in relation to a number of constituents occurring normally in a purified water supply.

5. Water works or purification plant engineers, the ones almost always held responsible for the water reaching consumers, should have control of distribution systems.

6. The copper, caustic alkalinity, and zinc limits in Appendix IV, U. S. Public Health Service Water Standards, should be made less strict. It is judicious to maintain the lead limit so as to be on the safe side. Limits for fluorides should be added and rather remotely, perhaps, limits for barium and selenium.

REFERENCES

(1) Riker, R. Public Works, **68**: 4; 24 (1937).
(2) Hart, W. B. Ind. Eng. Chem., Anal. Ed., **9**: 243 (1937).
(3) Peters, J. P. *Body Water*. Thomas, Springfield (Ill.), 1935.
(4) U. S. Pub. Health Reports, **40**: 693 (1925).
(5) Elvehjem, C. A. and Sherman, W. C. J. Biol. Chem., **98**: 309 (1932).
(6) Giordano, G. B. Atti. soc. sc. lett. Genova, **1**: 299 (1936).
(7) Harold, C. H. H. Metropolitan Water Board Report, London, 1935. C. A., **30**: 4957 (1936).
(8) Griffin, A. E. Am. J. Pub. Health, **27**: 226 (1937).
(9) Mitchell and Hamilton. Ill. Agr. Sta. 48th Ann. Report (1935).
(10) Hamilton, H. C. J. Am. Water Works Assoc., **10**: 773 (1923).
(11) U. S. Patent, #2,092,057. Sept. 7, 1937.
(12) McGhee, J. L. Science, **73**: 347 (1931) and personal correspondence.
(13) Usher, S. J., MacDermot, P. N. and Lozinski, E. Am. J. Dis. of Children, **49**: 642 (1935).
(14) Elvehjem, C. A., Duckles, D. and Mendenhall, D. R. Am. J. Dis. of Children, **53**: 785 (1937).
(15) Coulson, E. J., Remington, R. E. and Lynch, K. M. Investigational Report, #23, **1**: U. S. Dept. of Commerce, 1934.
(16) Schnetz, R. Klin. Wochsch., **16**: 664 (1937).
(17) Schneider, W. M. G. Cuivre and Laiton, **6**: 519 (1933); C. A., **28**: 1434 (1934).

(18) Froboese, V. Gas. u. Wasserfach., **77**: 225 (1934); C. A., **28**: 4508 (1934).
(19) Flinn, F. B. and Inouye, J. M. J. A. M. A., **90**: 1010 (1928).
(20) *Standard Methods of Water Analysis.* 8th Edition, American Public Health Association, New York, 1936.
(21) Bartow, E. and Weigle, O. M. Ind. Eng. Chem., **24**: 463 (1932).
(22) Wyllie, J. Can. Pub. Health Jour., **28**: 128 (1934).
(23) Wright, W., Sappington, C. O. and Rantoul, E. J. Indust. Hyg., **10**: 234 (1928).
(24) Kruse and Fischer. Bull. Hyg., **6**: 74 (1931).
(25) Thouvenet (cited in Paris letter). J. A. M. A., **97**: 654 (1931).
(26) Univ. of Aberdeen Report. Lancet, #2, 374 (1933); also Editorial. Lancet, #2, 1156 (1933).
(27) Ingleson, H. *Tech. Paper #4, The Action of water on lead with special reference to the supply of drinking water.* Dept. Sc. Ind. Res., His Majesty's Stationery Office, London, 1934.
(28) Lanza, A. J. J. A. M. A., **104**: 85 (1935).
(29) Howitt, H. K. and Cowgill, G. W. J. Biol. Chem., **119**: 553 (1937).
(30) Quam, G. N. and Klein, A. Am. J. Pub. Health, **26**: 778 (1936).
(31) Kehoe, R. A., Thamann, F. and Cholak, J. J. Indust. Hyg., **15**: 257 (1933).
(32) Kehoe, R. A., Thamann, F. and Cholak, J. J. A. M. A., **104**: 90 (1933).
(33) Traeger, H. and Schmidt, F. Z. ges. exptl. Med., **100**: 717 (1937).
(34) Devergie. Ann. d'hyg., **20**: 463 (1838).
(35) Elvehjem, C. A. and Hart, E. B. Am. J. Physiol., **119**: 768 (1937).
(36) Lewis, P. G. British Med. Jour., **2**: 158 (1911).
(37) Chase, E. S. J. Am. Water Works Assoc., **11**: 873 (1924).
(38) Myers, J. T. J. Infect. Dis., **36**: 566 (1925); ibid., **37**: 13 (1925).
(39) White, J. C. J. Am. Water Works Assoc., **14**: 406 (1925).
(40) Bernheim, A. R. J. A. M. A., **100**: 1001 (1933).
(41) Sherman, H. C. *The Chemistry of Food and Nutrition,* The MacMillan Company, New York City. 5th Edition, 1937.
(42) Committee Report. Ind. Eng. Chem., News Ed., **12**: 391 (1934).
(43) Hale, F. E. J. Am. Water Works Assoc., **27**: 1199 (1935).
(44) Heller, V. G. and Burke, A. D. J. Biol. Chem. **74**: 85 (1927).
(45) Drinker, C. K., Thompson, P. K. and Marsh, M. Am. J. Physiol., **81**: 284 (1927).
(46) Drinker, C. K. and Fairhall, L. T. U. S. Pub. Health Reports, **48**: #32, 955 (1933).
(47) Lothian, N. V. and Ward, A. R. J. Royal Army Med. Corps, **39**: 163 (1932).
(48) Anderson, E. A., Reinhard, C. E. and Hammel, W. D. J. Am. Water Works Assoc., **26**: 49 (1934).
(49) Simakov, P. V. Biokhimiya, **1**: 685 (1936); C. A., **31**: 7955 (1937).
(50) Miller, J. T. and Byers, H. G. Ind. Eng. Chem., News Edit., **13**: 456 (1935).
(51) Smith, M. I., Franke, K. W. and Westfall, B. B. U. S. Pub. Health Reports, **51**: 1496 (1936).
(52) Smith, M. I., Westfall, B. B. and Stohlman, E. F. U. S. Pub. Health Reports, **52**: 1171 (1937).

(53) DUDLEY, H. C. AND MILLER, J. W. U. S. Pub. Health Reports, **52**: 1217 (1937).
(54) SMITH, M. I. AND WESTFALL, B. B. U. S. Pub. Health Reports, **52**: 1375 (1937).
(55) SMITH, M. I., STOHLMAN, E. F. AND LITTLE, R. D. J. Pharmacol., **60**: 449 (1937).
(56) LOEPER, M. Progress Medical, 661 (1931).
(57) SCHOFIELD, C. S. AND WILCOX, L. V. Tech. Bull. #264, U. S. Dept. of Agriculture (1931). DERBY, R. L. J. Am. Water Works Assoc., **28**: 1449 (1936).
(58) CHERAMY, P. AND LEMOS, A. J. pharm. chim., **25**: 17 (1937).
(59) LOEB, L. B. J. Am. Water Works Assoc., **26**: 461 (1934).
(60) GIBBARD, J. Am. J. Pub. Health, **27**: 112 (1937).
(61) JUST, J. AND SZNIOLIS, A. J. Am. Water Works Assoc., **28**: 492 (1936).
(62) BOISSEVAIN, C. H. AND DREA, W. F. Endocrinology, **20**: 686 (1936).
(63) BRAIDECH, M. M. AND EMERY, F. H. J. Am. Water Works Assoc., **27**: 557 (1935).
(64) EAGER, J. M. U. S. Pub. Health Reports, **16**: 2576 (1901).
(65) GASPARINI, O. Arch. Form. Sper., **25**: 231 (1918).
(66) CHURCHILL, H. V. Ind. Eng. Chem., **23**: 996 (1931).
(67) SMITH, H. V. Am. J. Pub. Health, **25**: 434 (1925).
(68) MCKAY, F. S. J. Dent. Research, **10**: 561 (1930).
(69) KEMPF, C. A. AND MCKAY, F. S. U. S. Pub. Health Reports, **45**: 2923 (1930).
(70) KEHR, R. W. J. Am. Water Works Assoc., **23**: 214 (1931).
(71) SMITH, M. C., LANTZ, E. AND SMITH, H. S. Ariz. Expt. Sta. Tech. Bull., 254 (1931).
(72) MCCLURE, F. S. AND MITCHELL, H. H. J. Biol. Chem., **90**: 297 (1931).
(73) DEAN, H. T. AND ELVOVE, E. U. S. Pub. Health Reports, **50**: 1718 (1931).
(74) MCKAY, F. S. Water Works Engineering, **85**: 790 (1932).
(75) DEAN, H. T. U. S. Pub. Health Reports, **48**: 703 (1933).
(76) ELVOVE, E. U. S. Pub. Health Reports, **48**: 1219 (1933).
(77) BORUFF, C. S. Ind. Eng. Chem., **26**: 69 (1934).
(78) DEAN, H. T. J. Am. Dent. Assoc., **21**: 1421 (1934).
(79) SMITH, M. C. AND LEVERTON, R. M. Ind. Eng. Chem., **26**: 791 (1934).
(80) MCKEE, R. M. AND JOHNSON, W. S. ibid., **26**: 849 (1934).
(81) HART, E. B., PHILLIPS, P. H. AND BOHSTEDT, G. Am. J. Pub. Health, **24**: 936 (1934).
(82) RIDER, J. H. J. Am. Water Works Assoc., **27**: 1516 (1935).
(83) SMITH, R. R. J. Am. Dent. Assoc., **23**: 1725 (1936).
(84) VAN HORN, A. L. Ohio Conf. Water Purification, 16th Ann. Report, 1936.
(85) VAN HORN, A. L. Ohio State Med. Jour., **32**: 1207 (1936).
(86) SHORTT, H. E., PANDIT, C. G. AND RAGNAVACHARI, R. S. Indian Med. Gaz., **72**: 396 (1937).
(87) BAUER, J. T., BISHOP, P. A. AND WOLFF, W. A. Bull. Ayer Clin. Lab., Pennsylvania Hospital, **3**: 67 (1937).
(88) KEMPF, C. A., GREENWOOD, D. A. AND NELSON, V. E. J. Lab. Clin. Med., **22**: 1133 (1937).

(89) SCOTT, R. D. AND CO-WORKERS. J. Am. Water Works Assoc., **29**: 9 (1937).
(90) ABBOTT, G. A. North Dakota Geol. Survey, Bull. #9, Grand Forks, N. D. (1937).
(91) ROHOLM, KAJ. *Fluorine Intoxication*. H. K. Lewis and Co., Ltd. London (900 references) 1937.
(92) DEAN, H. T. AND ELVOVE, E. U. S. Pub. Health Reports, **52**: 1249 (1937).
(93) WOLPERT, N. N. Water Works Engineering, **86**: 1260 (1934).
(94) GRIFFIN, A. E. Am. J. Pub. Health, **26**: 719 (1936).
(95) BARYSHEVA, E. P. Arch. sci. biol. (U. S. S. R.), **40**: #3, 139 (1936).
(96) HELLER, V. G. AND PURSELL, L. Abst., J. Biol. Chem., **119**: 46 (1937).

TREATMENT OF NATURAL WATERS TO PREVENT AND CONTROL CORROSION

By C. W. Borgmann

The subject of corrosion and its prevention covers such a vast field that it is necessary to define closely the portion of the field under discussion. The present paper will concern itself with the treatment of natural ground waters for the control of corrosion of commercial ferrous materials. The environment, therefore, is a dilute and nearly neutral solution of the chlorides, sulfates, carbonates, and bicarbonates of sodium, potassium, calcium and magnesium. Both carbon dioxide and oxygen are usually present. Silica, salts of iron, manganese and aluminum, and organic matter may also be present. The metal to be protected is one which is readily corrodible by such solutions. The commercial surface is "weak" from the standpoint of susceptibility to corrosion and usually requires some means of protection if a prolonged life is to be realized. The environmental conditions are total immersion with a moving electrolyte. Uncontrolled corrosion may give rise to several unsatisfactory conditions such as "red water," decreased capacity of pipes, and short life for the distributing plant.

It may be well to review the known facts regarding corrosion of metals under the above conditions. The number of such facts is surprisingly small, due primarily to the difficulty of an adequate laboratory investigation under the defined conditions. However, the qualitative influence of certain factors can be given at this time. The presence of dissolved oxygen is necessary for material corrosion to occur under the given conditions, particularly at atmospheric temperatures. The rate of corrosion increases with the amount of oxygen available to the metallic surface. However, oxygen plays a secondary rôle in influencing the corrosion products formed and hence in certain cases a high oxygen content in solution gives a relatively low corrosion rate. The rust formed in this latter case is of

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A paper presented at the meeting of the North Carolina Section, August, 1937, by C. W. Borgmann of the Department of Metallurgy and Research of the National Tube Co. (Subsidiary of the U. S. Steel Corp.), Pittsburgh, Pa.

such a character that the diffusion of oxygen to the metal surface is greatly retarded (1). The hydrogen ion concentration (colloquially expressed as pH) within the range normally found in natural waters, has little influence on the rate of corrosion by waters containing little or no scale-forming salts (1) (2). However, with waters containing appreciable quantities of calcium and magnesium the pH is very important as will be discussed later. The amount of dissolved carbon dioxide in solution also has little effect on the rate of corrosion in soft waters, but is very important in waters containing any appreciable hardness. The influence of temperature (atmospheric differences) will be slight. Two opposed resultants of temperature are at work; i.e., the decrease in solubility of oxygen and the increase in reaction velocity with higher temperatures. The influence of velocity of flow is also complicated (3) (4). Oxygen may reach the metal surface more readily at higher velocities which causes either an enhanced corrosion rate or the formation of a "screening" rust layer with a consequent diminished rate of attack. The character and amount of the anions and/or cations present in the water may be important in determining the character of attack. Solutions of the alkaline chlorides are more corrosive than equivalent solutions of the alkali-earth chlorides (5), probably because of the slight solubility of the secondary alkaline-earth hydroxide formed at cathodic areas. Further, waters containing salts in a super-saturated solution (as for example $CaCO_3$) may deposit protective layers on the metal surface. Moreover, if the solution does not contain *slightly soluble salts*, the differences in concentration found in municipal supplies and the resultant change in the electrical resistance of the solution, will cause small differences in corrosion rates—the higher the conductivity, the greater the amount of corrosion (6).

We may discuss the corrosion of a reactive metal like iron in three types in solutions free from slightly soluble salts. First, and most commonly encountered under the conditions discussed, is general attack (Type 1). The conditions are severe and the entire area breaks down; fairly uniform rusting continues under a porous layer of corrosion products. Second, under less severe environmental conditions, as in soft natural waters to which has been added sodium hydroxide in critical amounts, only the "weakest" areas are attacked, with severe pitting resulting (Type 2). Less metal may be corroded, but failure will occur more rapidly due to the concentration of attack. The third type of corrosion is one where the environment

is such that a perfectly protective film is formed on the metal and corrosion is stifled completely by its products (Type 3). Corrosion of a metal in a water will be of one of these three types depending on the following factors:

Solution

1. Character and concentration of dissolved substances.
2. Temperature.
3. Movement of solution relative to metal.
4. pH of solution.

Metal

1. The state of surface film (number of susceptible points).
2. Type and geometrical location of corrosion product formed.
3. The existence of crevices, porosities and shielded areas.

In solutions, saturated with slightly soluble salts, a protective layer of such salts may be formed which will protect the iron mechanically.

We can now venture to give the possible methods of protection against corrosion in natural waters. The first method may be defined as the isolation of the metal from the solution by means of artificial coatings such as cement, paints, etc. The field of such protective coatings is outside the scope of the present paper and will not be discussed further.

The second method may be defined as the treatment of the corrosive environment with additions suitable for forming natural protective layers or films on the metal surface. Such methods may be logically divided into three groups. Firstly, additions of a slightly soluble salt, such as calcium carbonate, may be made to the water. The salt is deposited on the metal surface and a protective coating may thus be formed. Secondly, additions of an inhibitor (sodium chromate, sodium silicate, etc.) may be made to the water in sufficient quantities to maintain the surface film of oxide in a perfect state of repair. The dangers inherent in this method are discussed later. And thirdly, additions of substances (possibly similar in character to the usual inhibitors) may be made which would cause the rust layer to be less permeable to oxygen.

The third method may be defined as the addition to the metal of suitable alloying ingredients in order to cause the formation on the metal surface of natural, protective layers or films of the corrosion products. Additions can be made to give protection either of the second (perfect protection) or the third (retardation of corrosion rate) types as discussed under additions to the solution.

Other methods which may be employed, but which do not fall in any of the above classifications are (1) the removal of oxygen from the corroding solution and (2) the possibility of retarding the cathodic depolarization reaction by other means than the prevention of access of oxygen to the metal surface.

The economics of the problem, among other important considerations, must be studied in detail in order to decide which of the methods is to be employed. One will probably have to choose a different method for application to the water supply as a whole than might be best for a specific purpose. The following discussion is consequently divided into the consideration of general water supply treatment and the consideration of special treatments.

TREATMENT OF WATER SUPPLY AS A WHOLE

The best treatment to apply to any given water supply will naturally depend on obtaining the greatest savings for the community which is being supplied. One must balance such credit items as increased life of the distributing system, freedom from complaints of "red water," and better maintenance of capacity of flow against the debit items of cost of treatment, increased treatment costs for industrial plants, and increased soap consumption. Clearly, then, the question of treatment to apply, if any, is closely related to the character of the raw water supply and the nature of the customer's demands.

Possibly the best known and most successful treatment used for controlling corrosion is that of saturating the water with a slightly soluble constituent.* A layer of the slightly soluble material is precipitated on the walls of the pipe and retards further corrosive action. The usual salt used for this purpose is calcium carbonate—chiefly because it is present in nearly all waters and is inexpensive to use when additions (generally as calcium hydroxide) are necessary. Each natural water will have a definite equilibrium saturation value depending on the pH and hardness. Once this value is determined

* Editor's Note—When and if the additions of these substances have been demonstrated to have value in the prevention or control of corrosion, it will be necessary further to demonstrate *their safety* as a component of drinking water. Physiological chemists and sanitary engineers are not yet in accord when questioned concerning the addition of some of these materials when there is a possibility that the water may be used for drinking. Therefore, if their value to the metal as corrosion inhibitors is demonstrated, it must not be assumed that their safety to human beings is likewise demonstrated.

for a given water, simple control of the two variables at or near the equilibrium point will form and maintain a protective layer. The application of the method to water supplies is largely the work of J. R. Baylis (7) and consists in adding sufficient alkali to cause calcium carbonate to be precipitated. Lime, soda ash and caustic soda may be used depending on the economics of the problem. Hopkins, Armstrong, and Baylis (8) have studied the question of the best treatment for the *average American community* and find that for waters with an initial hardness below 75 p.p.m., lime treatment is the correct one. When high acidities are noted as due to free CO_2, a previous aeration may reduce the cost of lime treatment. Filters of burnt dolomite are used successfully in Germany for the addition of scale forming ingredients (9) to soft, acid waters.

The general use of silicates of soda (8 p.p.m.) for the control of corrosion has been recommended for municipal water supplies (10). Such treatment will undoubtedly serve to diminish "red water" troubles, but the results of Hale (11) throw considerable doubt on the benefits of such treatment on soft waters such as the New York City supply. The common error of concluding that corrosion has been stopped if "red water" troubles disappear should not be made. Probably, silicates tend to strengthen the surface layers if the water is reasonably hard naturally. Phosphates have also been suggested for use and here again the same criticism made regarding silicates probably holds. They will help in strengthening calcium salt layers, but a definite hardness is necessary before successful control is obtained.

The beneficial action of dissolved oxygen should be noted in passing. A plentiful supply seems to be necessary if the calcium carbonate method is to succeed. Air-free water will retain the carbonate in super-saturated solution. It seems that the rusting process helps to stifle itself by aiding in the deposition of carbonate.

SPECIAL TREATMENTS FOR SPECIFIC PURPOSES

The possibility of water treatment to prevent corrosion under specific conditions is also worthy of consideration. The treatment of water for boilers is such a case, but it has already received adequate consideration. In considering such cases, we must divide the conditions to be met into two classes; (1) the water is used once and run to waste and (2) the water may be recirculated and requires only a small amount of make-up. Water treatment of the first

class is difficult to apply economically except where the methods discussed under the treatment of the general water supply can be used. Other treatments are usually too expensive to consider. Hence, the following discussion will generally be applicable only to water which is recirculated. Certain exceptions will, of course, be met and will be noted as such.

The most common method of treatment is generally known as inhibition. Additions of such substances as soda ash, caustic soda, silicates of soda, sodium phosphates, sodium aluminate and sodium chromate (as dichromate and caustic soda) are known to prevent the corrosion of ferrous materials if made in sufficient quantities. They do so by keeping the natural oxide film on the ferrous materials in a constant state of repair. However, one should not fail to mention the dangers inherent in such a method, namely the rapid pitting that takes place when the inhibitor concentration is deficient (12). Recent unpublished work by the present author indicates that although the total corrosion may be reduced by the presence of an inhibitor, the rate of penetration is often increased by as much as 60 times. The above named inhibitors are anodic polarizers and the first protection is gained simply through the reduction of attacked area, with a consequent increased rate of penetration. The amount of inhibitor necessary for complete protection will vary depending on the several factors previously mentioned (p. 267). The results, when such treatments are successful, are highly satisfactory—but very careful control and continual observation are necessary to prevent disaster.

However, one can cite several examples of the successful use of solutions inhibited with chromates, phosphates, silicates or mixtures. The uses include treatment of the water in air-conditioning systems (13), cooling water for ammonia condensers (14), cooling water in the oil industry (15), cooling of internal combustion engines (16), cooling of power rectifiers (17), etc. In general, it may be said that success is met when it is economically permissible to use a high concentration of inhibitor and that hard waters are generally safer to inhibit than soft ones.

The use of silicate treatment of domestic hot water supplies and water supplies for laundries and textile plants is of interest (18). Such additions aid in the deposition of an insoluble scale without increasing the hardness of the water. A partially hard water, however, lends itself more readily to this treatment than a soft water.

The removal of dissolved oxygen by deactivators using chemicals

or scrap metal or by deaerators using mechanical or thermal means is well known (19). Such methods, where economically feasible (as in a closed system) are exceedingly valuable. The amount of corrosion is decreased without concentrating the attack.

The future may hold much in store in connection with the better control of underwater corrosion. For example, zinc and nickel salts (20) are known to retard the corrosion of ferrous metals and further, usually insure a general type of attack. Certain polyhydric alcohols (21) act as restrainers of corrosion in neutral liquids. It has long been known that certain colloids in pure water or buffered solutions reduce the amount of corrosion (22). Emulsifying oils (23) and certain clays (24) serve to retard failure due to corrosion-fatigue. These isolated examples, while of no wide importance in themselves, indicate the range of possibilities in the future control of corrosion.

The final method, regarding which little or nothing is known, is the addition to the water of substances (often similar to those added for complete inhibition) which will influence the rust layer so as to retard the rate at which oxygen reaches the metal surface. The indications that such a method is possible are few in number, but are convincing. The amounts of added materials would be small. Considerable work needs to be done in this field before any definite conclusions can be reached regarding its value.

RECENT METALLURGICAL ADVANCES IN THE FIELD OF CORROSION CONTROL

In closing it might be well to add a few words on the subject of corrosion by natural waters from the standpoint of recent metallurgical developments. Stainless steels, containing chromium or chromium and nickel are well known. Although such materials are not capable of economic general use for water supplies, the nature of their resistance to corrosion is illuminating. An exceedingly thin but impermeable film of oxide is the reason for the resistance of such alloys. A comparison is permissible with totally inhibited steel. Corrosion of stainless steel, where it occurs, is often of the pitting type.

For many years now, it has been believed that the presence of small amounts of alloying ingredients in iron or steel would not markedly influence the rate of corrosion in neutral waters. The results of the A. S. T. M. tests (25) indicated that such was the case. However, a low alloy steel containing chromium, copper and phosphorus—introduced because of its enhanced resistance to atmospheric

corrosion—has given quite encouraging results under totally immersed conditions, particularly in strong salt solutions. There are also encouraging possibilities that low alloy steels having enhanced resistance to fresh waters will not be long in development. The resistance of such steels seems to be due to the character of the rust layer and its ability to retard oxygen from reaching the metal surface—comparable with the suggested possibility of treatment of waters with low concentrations of inhibitors.

REFERENCES

1. E. C. Groesbeck and L. J. Waldron. Proc. A. S. T. M., **31**: II: 285 (1931).
2. W. R. Whitman, R. P. Russell, and V. J. Altieri. Ind. Eng. Chem., **16**: 668 (1924).
3. F. N. Speller. *Corrosion: Causes and Prevention.* McGraw-Hill Book Company, New York, Second Edition (1935), p. 156.
4. L. J. Waldron and E. C. Groesbeck. Proc. A. S. T. M., **34**: II: 128 (1934).
5. C. W. Borgmann. Ind. Eng. Chem., **29**: 816 (1937).
6. U. R. Evans and T. P. Hoar. Proc. Roy. Soc. (London), A **137**: 359 (1932).
7. J. R. Baylis. Ind. Eng. Chem., **18**: 370 (1926); **19**: 777 (1927); **20**: 1191 (1928).
8. E. S. Hopkins, J. W. Armstrong, and J. R. Baylis. Ind. Eng. Chem., **26**: 250 (1934).
9. E. Naumann. Korrosionstagung, **5**: 78 (1935).
10. W. Stericker. Paper presented before the meeting of the American Chemical Society, Omaha, Nebraska, 1937.
11. F. E. Hale. Jl. Am. W. W. Assoc., **26**: 1315 (1931); **27**: 1119 (1935).
12. U. R. Evans. *Metallic Corrosion, Protection and Passivity.* Edward Arnold & Co., London, 1st Edition, 1937.
13. C. M. Sterne. Proc. A. S. T. M., **35**: II: 261 (1935).
14. W. G. Whitman, E. L. Chappell, and J. K. Roberts. Refrigerating Eng. **12**: 155 (1925).
15. W. R. Finney and H. W. Young. Petroleum World, **24**: 9 (1927).
16. W. O. Kroenig and S. E. Pawlow. Korrosion u. Metalls., **9**: 268 (1933).
17. C. van Brunt and E. J. Remsheid. General Elec. Rev., **39**: 128 (1936).
18. F. N. Speller. See 3 above. p. 366.
19. F. N. Speller. See 3 above—chapter X.
20. U. R. Evans. See 12 above. p. 180.
21. W. S. Patterson and R. C. A. Culbert. J. Soc. Chem. Ind., **54**: 327 T (1935).
22. J. A. N. Friend and R. H. Vallance. J. Chem. Soc., **121**: 466 (1922).
23. S. F. Dorey. Trans. Inst. Nav. Arch., **75**: 210 (1933).
24. F. N. Speller. American Petroleum Inst., 1935; Oil Gas Jl., 34, Nov. 14 (1935).
25. V. V. Kendall and E. S. Taylerson. Proc. A. S. T. M., **29**: II: 204 (1929).

THE CAYUGA FILTER PLANT

By C. E. Elmendorf

The story of Cayuga's water supply development is of a type with which all too many of us are very familiar,—that of stretching a limited and predetermined sum of money so as to cover not only absolute necessities, but an occasional luxury.

Cayuga is a small village on the east shore of Cayuga Lake. It has a resident population of about 350 people the year around, with 150 additional in the summer. The only industry in the village is the Beacon Milling Company which makes chicken and cattle feeds. Naturally, with a village this size, the amount of money which could be spent for a water supply was very limited and the record of the job is one of constant economies. The local authorities, before the project was started, figured that $40,000.00 was all they could expend for the water works system. The least cost for which the distribution system and storage tank could be built amounted to $25,000.00. This left just $15,000.00 with which to get the village a water supply.

Most communities this size depend upon wells or springs for their water. In and near Cayuga there isn't a well or spring of sufficient size to consider. The Milling Company, at their experimental farm, had a well drilled into rock which gave extremely hard water containing sulphur, iron and having an unpleasant taste. Apparently the experimental chickens didn't mind. Other wells were studied with no better success, so a well as a possible source of village water supply was out.

Cayuga Lake at the village's front door was an obvious source of supply. The trouble with the lake was the quality of the water and the cost of developing a supply from it. The $15,000.00 had to cover an intake and a complete treatment works.

To construct a long intake out in the lake was out of the question due to expense. We, therefore, had to decide on a shorter one.

A paper presented before the New York Section meeting at Schenectady, October 1, 1937. The author is an associate of William S. Lozier, Inc. of Rochester, N. Y.

The point selected for this intake was along the Lake near the village south limits away from the center of population. At this point water could be taken about 400 feet out from the shore at a depth of 7 or 8 feet and near the Barge Canal channel which carries the flow of the lake. The water so obtained, though of generally good quality, was subject to turbidity, taste and odor. These arose from shallowness of the lake and growth of weeds and algae.

The intake was constructed of cast iron pipe with bolted Anthony joints. At the end of the pipe was placed an ell pointing up sur-

EXTERIOR VIEW OF CAYUGA FILTER PLANT

mounted by a copper screen. This screen consisted of mesh made up of number 8 gauge copper wire on a frame work of copper bars. To protect the end of the intake from ice and floating debris as well as to hold it in position, a concrete block was placed. This block was 9.5 feet square on the base. Above the pipe line the sides of the block were beveled so as to present a sloping surface better to divert floating debris. The center of the block from the top to the base where the pipe rests, was cut out in the shape of a Maltese cross, leaving openings through which the water could circulate to

the screen. This arrangement proved quite economical as the Contractor built his form on the shore, towed it into position and sunk it to the bottom. The concrete was then tremied into the form. It was considered that this type of structure was considerably cheaper and much more satisfactory than the usual type of crib.

In designing the treatment plant, two things had to be considered, first there was a definite limit to the original expense; and second, the operating cost must be kept to a minimum. To treat the lake

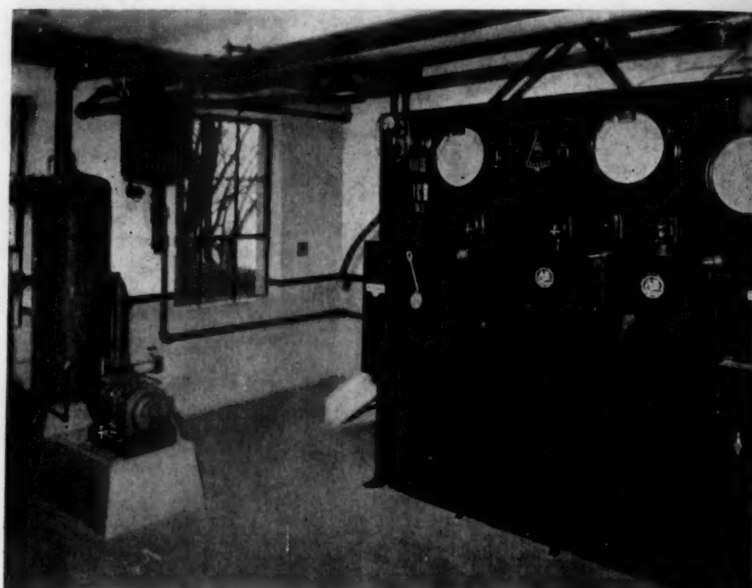
FIRST FLOOR VIEW OF CAYUGA FILTER PLANT

water properly, it was decided that, due to the flexibility of the rapid sand filter, this was the most suitable type. It was estimated that the plant would have to treat about 50,000 gallons per day. To reduce the operating time to a minimum it was decided to design the plant for a rate of 200,000 gallons per day.

The plant, as laid out, consisted of (1) an aerator of the Aer-O-Mix type in a basin with a detention period of 20 minutes, (2) a sedimentation basin with a capacity of 27,000 gallons which would give between three and four hours detention, (3) two rapid sand filters

5 x 7 feet,—each with a capacity of 70 gallons per minute and (4) a clear water well of 22,000 gallon capacity. After the plant had been laid out an estimate was prepared and it was decided to equip only one of the filters until a load was built up sufficient to require the two.

Of course, with this plant, all of the water used had to be pumped twice;—the low-lift pumps raising the water from the lake to the aerator and the high-lift pumps to lift it from the clear well to the standpipe. In the design and arrangement of the pumping equip-



Basement View of Cayuga Filter Plant

ment, thought was given to not only economy of installation but future economy in operation. Low capacities were used to avoid high electric demand charges. To reduce the amount of attention required it was desirable to make the operation as automatic as possible. It was also necessary to provide standby equipment. The low lift pump as installed was designed to handle 75 gallons per minute. This was kept slightly in excess of the filter rate to assure that there would be plenty of water at all times to run the filter at its rated capacity. The high lift pumps were designed for 150 gallons per minute under average conditions. With the small size

of clear well and the high electric demand charge there was no point to placing a larger pump. On the other hand, this pump having slightly more capacity than the two filters, would be able to keep the clear well down during the filtering period even when both filters were installed.

For washing the filters a 400 gallon per minute pump was provided in order to give a washing rate of 12 gallons per square foot per minute. On this item too, comparisons were made and it was found that the pump costing $300.00 was more economical than an over-head tank with a water level control valve fed from the high lift pumps. Also there would be a saving in power as the pump for washing would not require the head that the high lift pumps worked against.

The service pumps were all designed with 60 cycle motors. As standby unit, both an extra high lift pump and a low lift pump were provided with one gasoline engine arranged to drive them. A comparison was made between locating the pumps so the suction lines would be flooded at all times or providing an automatic priming system or equipping each pump with priming tank. The priming tank was the cheaper to install and therefore selected.

The operation of the high lift pump was arranged to be automatically controlled by the water level in the standpipe. This was desirable so as to keep the tank full at all times thereby providing full fire protection, and at the same time to prevent unnecessary overflow of the tank. To accomplish this, a Foxboro Rotax Pressure Controller was installed at the plant. With automatic control on the pump, there was the possibility of the pump emptying the clear well and operating without any load. To prevent this a Foxboro Rotax Liquid Level Controller was installed to operate on the level of the water in the clear well. This arrangement on the one hand prevented the high lift pump from running when the clear well might be empty and on the other hand the low lift pump from running and flooding the clear well when it might be full.

The electric lines controlling the chemical feeders were tied into this control so that they would similarly start and stop operation. To prevent the filter from draining at time of shutdown, a hydraulic valve was installed to close automatically as the low lift pump stopped.

On the Rotax controllers a recording mechanism was used in each case so as to give the operator a record of performance. The purpose of these controllers was primarily to maintain economy in opera-

tion. It was felt that the $200.00 additional expense for the automatic and recording features would be more than saved in power and improved operation. In selection of the equipment to be used in the treatment the same considerations governed. It was also desired to give the operator all necessary equipment so that he could meet the problems of taste, odor and turbidity. For chlorination, arrangements were made so that either post or pre-chlorination could be used. Because of the small size of the installation, the semi-automatic rotor type Wallace & Tiernan Vacuum Chlorinator, which had just come on the market, was selected. Similar thought was given to the selection of the chemical feed machine. For this an International Disc type dry feed machine which had a low capacity and could be used for feeding either carbon, alum or a mixture was used.

Considerable thought was given to the selection of mixing equipment. The extremely low flows would not lend themselves to a baffle type mixing basin. It was also felt that it was desirable to provide aeration. This would eliminate from the water entrained gases and might be of some assistance in reducing tastes and odors. The Aer-O-Mix, made by the Vogt Manufacturing Company, was selected as combining these two functions of mixing and aerating. This device also could be designed for the low rate of operation.

To allow for a long settling time the sedimentation tank was designed for three to four hours detention.

In the design of the filters themselves, economy was practiced wherever possible. The influent was admitted through the far end of the wash trough. The collection system at the bottom of the filter was made up of 2 inch perforated pipes spaced 2 feet on centers. The outlet for the wash water was taken directly off the end of the trough instead of the more common practice of a receiving well at the end of the filter. For operating the filter, there was installed an International Rate Controller feeding into the clear well and an indicating loss in head gauge.

To measure the consumption of the village and keep a constant check on plant operation, a meter was installed on the line leaving the plant. As the pumping rate to the standpipe was practically a constant quantity an orifice type meter made by the Simplex Valve and Meter Company was selected as being the most economical.

In constructing the sedimentation basin and clear water basin reinforced concrete was used. Thought was given to the compactness of arrangement of these tanks, the wall of the filter serving as one wall

of the settling tank and the filters being designed over the clear water basin. All tanks were thoroughly waterproofed.

When it came to the building to house the plant, economy was necessary. The structure was built of cinder block plastered with cement mortar on the outside and with a wood roof. Originally it was planned that the operating floor and stairs would be made of wood but an extra appropriation was obtained and concrete and steel substituted.

When completed the filter plant and intake cost $15,670.00. $3,670.00 had gone for the chlorinator, chemical feeders, Aer-O-Mix and filter equipment; $3,970.00 for the five pumps, their connections and controls; $4,000.00 for the concrete tanks, filters and clear well. $1,520.00 built the intake and $2,510.00 had been spent for the building.

The plant was not the structure we would have liked to have had if there had not been a limit on the cost, but it was a permanent one —completely equipped to handle the water and to give satisfactory results with the lowest possible operating cost.

The system has now been in operation for 2½ years. Instead of the anticipated 40 consumers there are 86. The per capita consumption is low. The daily pumpage runs from about 13,000 gallons per day in winter to about 32,000 gallons per day in summer. The August average was 26,400.

About 8,000 gallons per day is used in summer by the Milling Company for air conditioning. The filter in the summer runs 20 to 30 hours between washings.

The daily chemical dosages are 4–5 pounds of alum, 2 pounds of carbon, 3 ounces of ammonium sulphate and 3 to 4 ounces of chlorine. At present very little taste can be noticed. The low water temperature in the winter has made it difficult to secure a proper floc.

Difficulty has been encountered in the operation of some of the equipment; the electrical power instead of being 60 cycles is 62½ cycles. This increased the speed of the motors and thus the capacity of the centrifugal pumps causing an electrical overload. A smaller pump impeller was installed to correct this trouble.

Beyond minor adjustments this plant has been unusually free from trouble and a plentiful supply of good water has been obtained for the village. The statement has been made by the Mayor and various taxpayers, that they would not now do without the plant for double its initial cost.

THE PALMYRA FILTER PLANT

By A. Bradford Squire

In discussing the Palmyra filter plant, it is necessary to digress from the treatment problem alone to discuss the entire project. The location of the intake vitally affected the treatment and the situation regarding the water for industrial use was unique.

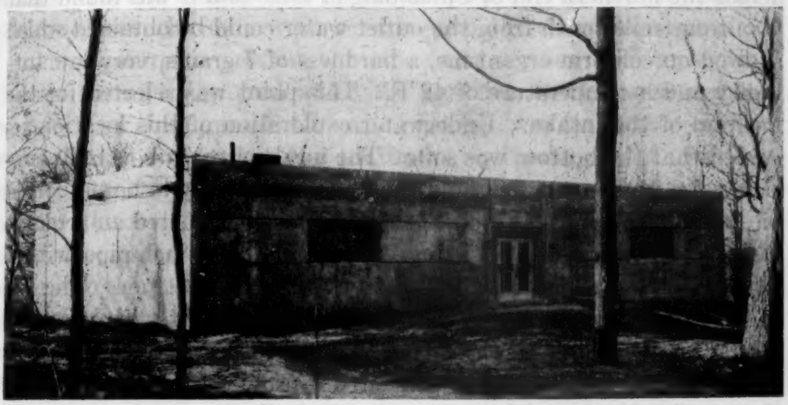
Palmyra was different. The village for years had a water supply. The water was hard, distasteful to drink and there wasn't enough of it. The leading industry was dependent on a muddy pool of creek water which was used over for cooling so many times that the pool in summer reached a temperature of 120°F. The village searched the neighborhood for more water. A small impounding reservoir with a filter was built on a drainage stream. The reservoir promptly silted up and the water obtained was even less palatable than what they had before. Shallow wells were dug which dried up in hot weather and deep wells penetrated the salt strata. There simply was no decent water supply in or near Palmyra.

After all this searching for water, we were retained to find a suitable water supply. Examination of the geology of the region confirmed what the village had found by putting holes in the ground—that there was no hope of an underground supply. The land around Palmyra is flat with no streams of any magnitude nor with a sustained year around flow. To get a real supply of water meant going a considerable distance. After a detailed study a gravity supply from Canandaigua Lake was recommended as the best source, with Lake Ontario, which is the same distance away, a poor second choice because of the high pumping cost.

Although the population served by the village system was close to 3,000 persons it was found that the average water consumption was less than 100,000 gallons per day with a maximum of 120,000. This arose from three causes: first, the necessary restrictions which the board had to place on the use of water; second, the large number

A paper presented before the New York Section meeting at Schenectady, October 1, 1937. The author is an associate of William S. Lozier, Inc. of Rochester, N. Y.

of cisterns in use in the village; and, third, the absence of manufacturing plants from the water rolls. Computing from the population it was estimated that the current requirements should be 200,000 gallons per day average and to allow for expansion and to take care of the summer peaks, 500,000 gallons per day was used as a basis for design of the pipe line. At this point the leading manufacturing plant approached the Board and said "See here, if you are getting a new water supply, we need water too. Our competitors all have good water in large quantities from public supplies and if we are to stay in business we need the same. Furthermore, we are willing to pay for it." When the board heard this last, they became interested and it later developed that the revenue from the sale of water to the manufacturing company would pay all the interest and other costs,



EXTERIOR VIEW OF PALMYRA FILTER PLANT

leaving only the principal to be paid by the village. The problem was then to obtain sufficient water for the domestic consumers and the manufacturing company's needs. Upon inquiry of the company officials it was found that the needs would amount to about three quarters of a million gallons per day. This additional quantity would ordinarily have meant the pipe line and treatment works had to be increased very considerably in size. However, it was found upon further examination and study, that as the water was to be used entirely for manufacturing and processing rubber and metal products, there was no point in treating this water. Further, it was found that whereas the village reservoir would give a pressure at the plant of 100 pounds, 30 pounds would meet all the requirements of the company.

To take care of the company it was then determined to increase the size of the pipe line slightly and to divide the flow where it entered the village by a connection to the village reservoir and another direct connection to the manufacturing plant. With this arrangement the pipe line could either deliver 900,000 gallons per day to the village reservoir or a million and a half gallons per day at reduced pressure to the company. Separating the connections in this way would permit the village to treat the water which was to be used domestically but save this expense on the water used for manufacturing purposes.

In 1935 the pipe lines and intake were constructed and in the following year the filter plant was built. Considerable study was given to the location of the intake. It was exceedingly desirable to secure water with as low a temperature as possible. Samples were taken across the northern end of Canandaigua Lake and it was found that about one mile south from the outlet water could be obtained which showed no coliform organisms, a hardness of 7 grains, very low turbidity and a temperature of 42°F. This point was selected for the location of the intake. Underwater exploration of this location revealed that the bottom was soft. The intake structure as built consisted of a timber mat weighted down just sufficiently to be supported on the soft bottom. On top of the mat was constructed an arrangement of intake pipes consisting of a header of 20-inch pipe with 6 vertical intake risers extending 8 feet above the bottom. The top of each riser was 30 inches in diameter and capped with a conical screen made of 8 gauge sheet copper punched with ½-inch holes.

The placing of this intake presented a problem to the contractor. To handle the material a boat was especially constructed using oil barrels. On this a derrick was mounted. The intake pipes were assembled on the timber mat at the dock at Canandaigua and towed out to the final position. There the mat was weighted with rock and gradually lowered into position. But the contractor tried to hurry up the job and lowered the mat too rapidly. As a result the whole assembly turned over under water—leaving the pipes on the underside of the mat. Fortunately they were securely anchored to the mat and did not drop to the bottom. The mat was righted by carrying hoisting lines underneath to the inside and turning it over.

The pipe line from the intake was similarly supported by timber mats, one of which was placed at each end of each 40-foot length. The pipes were mounted on the mats at the dock, towed into position in the pipe line, water was then admitted to the pipe and it was

lowered to the bottom. Couplings under water were joined by a diver.

Because of the importance of maintaining the quantity of flow in the pipe line it was determined to coat the inside of the pipe line with $\frac{1}{16}$ inch of bitumastic enamel. Alternate bids were received for steel and cast iron pipe. The bid for steel pipe with an outside bitumastic coating $\frac{3}{32}$ inch thick was approximately $50,000.00 below other materials and the contract awarded on this basis. The pipe line ran in size from 20 inches to 12 inches, the sizes being selected so as to give the least cut possible at the high end and still maintain the hydraulic gradient to both the reservoir and the plant. Plain end pipe in 40-foot lengths was used for most of the line. Around curves shorter lengths of pipe were used with a few specially made up welded steel fittings. On the land section of the line standard Dresser couplings were used. On the underwater section special Dresser couplings with a locking feature to prevent the pipe from slipping were provided. The contour of the ground which the pipe line crossed was very irregular. For the upper 7 miles the pipe line was laid to a straight grade about 1 foot below the maximum hydraulic grade. In the lower section the pipe line followed the surface of the ground with a cover of $3\frac{1}{2}$ to $4\frac{1}{2}$ feet. Along the 18 miles of pipe line there were provided 11 gate valves, 14 Simplex vacuum valves designed to admit air into the pipe line when it was empty and 22 Simplex air valves designed to release accumulated air from high points in the line. Each of these was placed in a water tight manhole. Blow-offs were provided at the low points.

On the line in the village which went to the manufacturing plant it was necessary to cross the Barge Canal. The crossing was made by supporting the pipe on a structure built of angles, plates and channels along the highway bridge. The pipe line was supported on rollers spaced 6 feet apart. The pipe was wrapped with three layers of asbestos felt coated with asphalt and held in place with copper rings. At each roller there was placed a $\frac{1}{4}$-inch steel bearing plate. At one end of the bridge there was provided an expansion coupling and a combination air and vacuum valve housed in a wooden structure. These precautions have withstood the extremely hard winter weather conditions where the pipe is located. Further, no leakage has developed in the crossing.

At all bends along the pipe line concrete backing was placed. At highway and railroads a large casing pipe was jacked underneath the

road in which the pipe line was placed. As one of the requirements of the Water Power and Control Commission, there was a stipulation that limited the village to 1,500,000 gallons of water per day which was placed at the instance of Canandaigua which also gets its water supply from Lake Canandaigua. At Shortsville, midway between the Lake and Palmyra, a Sparling meter was installed so that a check could be kept on this quantity.

The work of installing the pipe line was done by the Cornell Contracting Company of New York. The pipe was furnished by the American Rolling Mills. The pipe line when completed was tested for leakage and none could be detected.

The pipe line enters the village at the old water works pumping station. This station was reconditioned. One of the old pumps was left as a standby to pump from the well in case of a break in the line from the Lake. Controls were placed for dividing the flow to the manufacturing plant from the village flow.

According to the arrangement which was made with the company, they were to receive the full flow of the line during the day time and all water over and above the village's needs at night. As the company pressure was much lower than village pressure the flow to the company could be turned off and on by an electrically operated hydraulic valve on their main feed line. The closing of this valve would send all water to the village reservoir. This quantity was far in excess of what the village needed and to divide this flow a special device was designed. This was installed by the Foxboro Company. It was originally planned and installed as a venturi tube to measure the flow on the line to the village reservoir controlling a "Stabil-Flow" or a V-port valve arranged to pass just the required amount to the village. It was planned that the same mechanism would open the hydraulic valve on the company line a sufficient amount to permit the surplus to enter that line. When this was placed in operation it was found that the hydraulic valve was not sensitive enough to give the adjustment required. To accomplish the operation it was necessary to build up a head loss in the company line great enough to send just the right amount of water to the reservoir. When the hydraulic valve failed to give the required accuracy, a bypass was constructed around the valve in which was placed a controlling orifice designed to fit the exact conditions. At the old pumping plant there was also installed a Wallace-Tiernan Chlorinator and its appurtenances. Meters were placed on both the company and

village lines and a Foxboro Rotax Altitude Controller was installed. This is arranged so that whenever the reservoir is full the hydraulic valve on the company line is automatically operated.

The filter plant for treating the water for the village was installed in the following year. Due to the excellent characteristics of the water, the problem was simple. Turbidity was negligible and there was no taste or odor to contend with. There was sufficient head available so that the plant could be operated by gravity but it was desirable to keep the head losses to a minimum and the capacity of the supply pipe to a maximum.

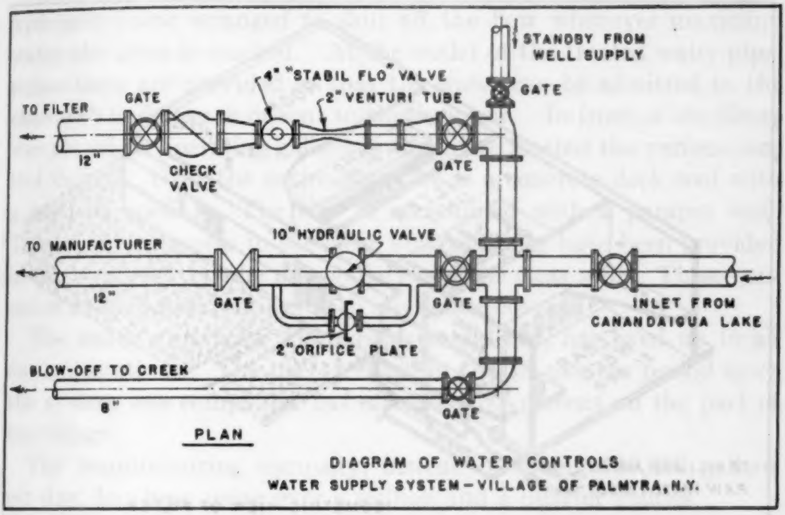


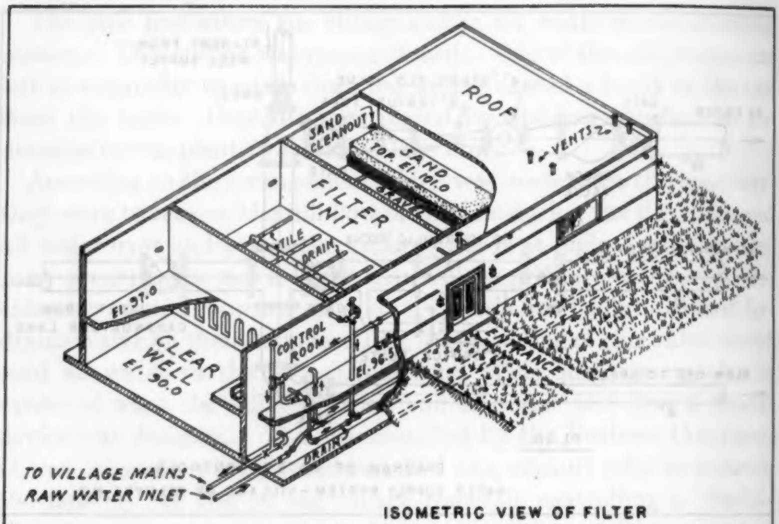
DIAGRAM OF WATER CONTROLS
WATER SUPPLY SYSTEM—VILLAGE OF PALMYRA, N.Y.

Estimates were prepared for both a slow sand filter and a rapid sand filter. As the water had to be treated after it had entered the village, the location of the plant, if it was to be gravity operated, had to be on the hill with the reservoir which is the highest point in the village. The difference in cost between the two types of filters at this location was negligible and the operating cost of the rapid sand filter which entailed both power and labor made the decision in favor of the slow sand filter.

The filter plant consists of a concrete masonry structure, most of which is above ground. As the plant is located in a village park its outward appearance was designed to harmonize with its surroundings. The lower 6 feet of the structure is a clear water storage basin which

was installed so as to increase the amount of filtered water available at times of fire. This has a capacity of 125,000 gallons. Above the storage basin are four filter units each 35 feet long by 20 feet wide.

Each unit is designed to filter at the rate of 80,000 gallons per day which is equal to a rate of 5,000,000 gallons per acre per day. The filter beds have tile under-drains covered with 18 inches of graded gravel laid down in 3 inch layers. The grading varying from coarse gravel at the bottom to fine sand at the stop. The main drains are 6 inch pipes with 3 inch lateral spaced 5 feet apart. Over the gravel there is placed 3 feet of filter sand.



ISOMETRIC VIEW OF FILTER
WATER SUPPLY SYSTEM—VILLAGE OF PALMYRA, N.Y.

To obtain the proper grading on the filter sand arrangements were made with the Ontario Sand and Gravel Co., Inc. of Oaks Corners, New York, owners of a local pit who had a very fine quality sand, to screen the sand twice. The results were very satisfactory and a sand of an effective size of 0.26 mm. and a uniformity coefficient of 2.0 was obtained. Four filter units were designed so as to keep to a minimum the effective areas out of service during times of cleaning.

The filters are arranged so that when they are started initially water can be admitted through the bottom. On the outlet of the unit, rate controllers have been installed so as to assure uniformity of rates of filtration. A connection to the drain is also provided for the

waste water. The inlet to the filter is over a trough located below high water level. Overflows are provided on each unit to prevent flooding of the structures. Inasmuch as the filters are above ground, considerable thought was given to the removal and addition of sand. For removing sand 12-inch pipes with water-tight covers have been placed in each bed just above the sand level. These pipes are arranged so that a truck or receiving hopper can be placed underneath them. Two hatchways are provided in the roof over each unit, which it is intended to use in connection with a sand loading machine for adding additional sand.

The water entering the filter plant is controlled by a float operated hydraulic valve arranged to shut off the flow whenever maximum water elevation is reached. At the outlet of the treated water pipe, connections are provided so that the water can be admitted to the clear well underneath or sent to the reservoir. In front of the filters was placed an operating gallery in which are located the various control valves. Over the entire structure is a concrete deck roof with a built-up roofing. The roof is surrounded with a parapet wall. To provide for access to the clear well, openings have been provided in the wall between the pipe gallery and the clear well. These consist of 24-inch wall castings with steel plate covers.

The water supply for Palmyra as completed, has lived up to all our expectations. The use of water in the 18 months period since the system was completed has increased 50 percent on the part of the village.

The manufacturing company, instead of taking 750,000 gallons per day, has been using over a million and a quarter gallons.

The filter plant, as constructed, has harmonized with the surroundings in the village park and its operation has been eminently satisfactory. The village has continuously received a water which at no time has had a temperature in excess of 60°F. and which averages around 50°F. The flow in the pipe line exceeds the design by 33 percent and including the many curves, control, valves and reducers the overall coefficient is 130.

Since the plant was placed in operation, the filter sand has not been cleaned or touched. In spite of the length of time of operation the loss in head is negligible. A few minor difficulties had to be ironed out. The control, as originally placed, for dividing water was set for 30,000 gallons per hour to the company at night. Their requirements have increased and at first they obtained the necessary quan-

tity of water by reducing their residual pressure below the 30 pounds. This created an extremely undesirable condition at the control plant. To quote the operator "It was the sound of a continuous freight train going through the plant whenever this occurred." This situation is now being met by installing a different orifice plate which is designed to take care of the increased requirements of the company.

In the filter plant it has been found that the temperature of the water caused excessive condensation on the pipes in the pipe gallery. This is to be taken care of either by insulating the pipes or providing drainage from them. On the whole, the job is one which we can point to with pride.

The construction cost of the Palmyra work when completed amount to $312,651.09. Of this, $38,777.42 was for the intake in Canandaigua Lake and $29,377.48 for the filter plant. The cost of the controls and chlorinators amounted to $4,843.27 and the remainder was for some 92,000 feet of pipe line.

UNDERGROUND WATER RESOURCES OF LONG ISLAND

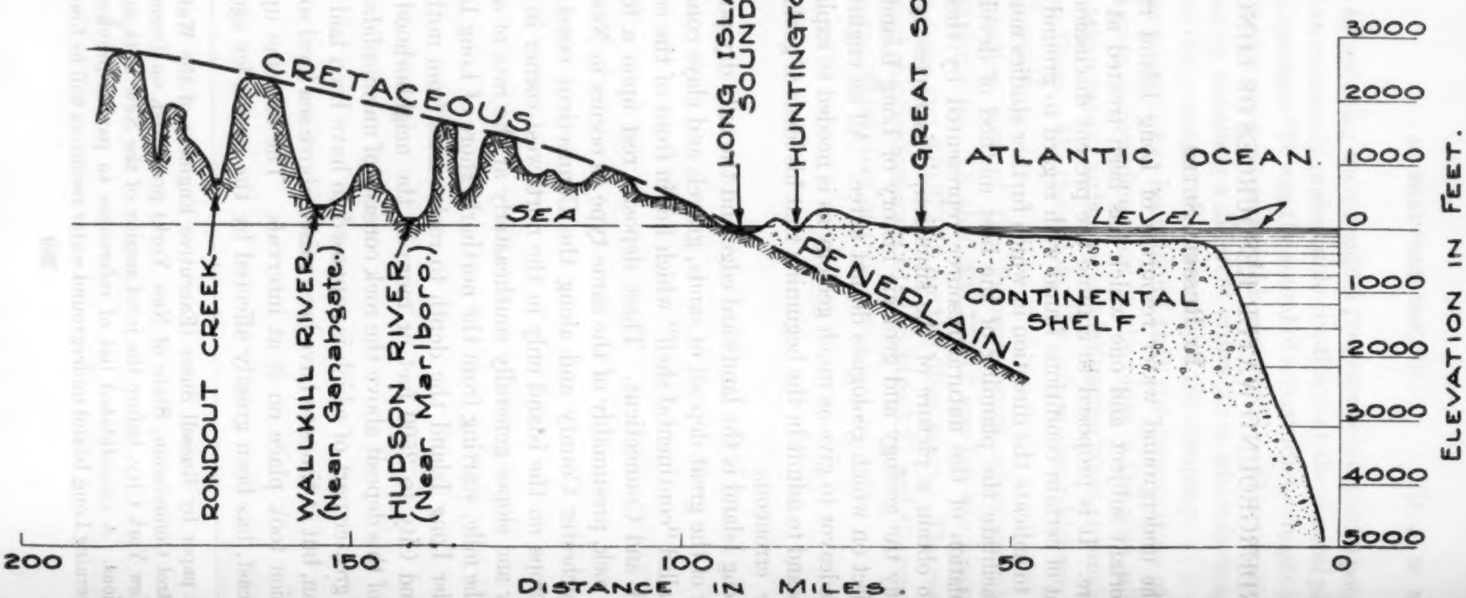
By Russell Suter

The underground water resources of Long Island constitute an important subject and one which has been treated at length elsewhere. It is proposed to confine the present discussion to a statement of certain conditions found with regard to ground water levels and to indicate the direction in which further studies must be pushed to facilitate the planning of the best method of development and regulation of the natural resource represented by these waters.

To obtain a picture of the situation, it is necessary to consider briefly the geology and geologic history of Long Island. This is a subject on which geologists do not agree. All an engineer can do is to endeavor to give as much geology as is needed to explain his problems and to admit in the beginning that his ideas of geology are probably erroneous.

Long Island is the landward edge and the only dry portion of that part of the great deposit of sands, gravels and clays constituting the so-called "continental shelf" which lies in front of the coasts of New York and Connecticut. These deposits rest upon a foundation of bed rock, presumably of the same type as occurs in New York City, Westchester County and along the Connecticut coast. This rock outcrops on the island only in the northwest corner in Long Island City and slopes generally southeasterly at the rate of about 60 feet to the mile, starting from the northerly shore of Long Island Sound. Under Long Island the depth to rock varies from nothing in Long Island City to 2500 feet or more in the neighborhood of Sayville. All of this deposit above the rock consists of unconsolidated material, the greater part of which is supposed to have been laid down in the ocean, but at times to have been raised above sea level so that normal erosion took place on it at intervals. The extreme upper surface, at least, has been greatly affected by the recent ice age.

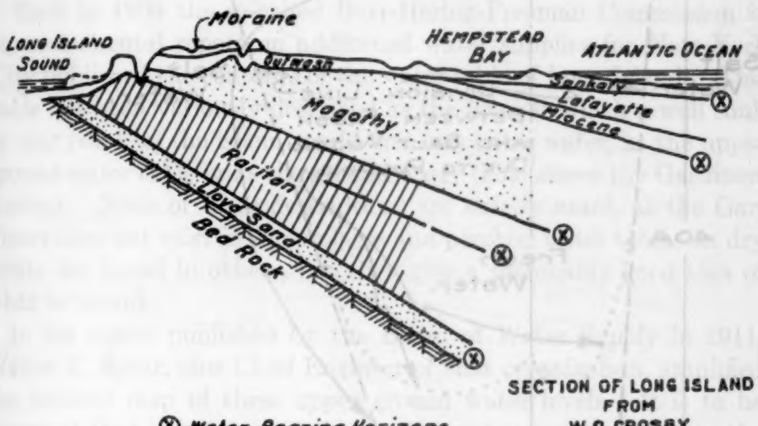
A paper by Russell Suter (Executive Engineer of the Water Power and Control Commission, State of New York) presented, on December 29, 1937, in New York City, before the joint session of the New York and New Jersey sections. A consolidated list of references to papers previously published concerning Long Island underground water resources will be found on page 324.



SECTION ACROSS ATLANTIC COAST SHOWING CRETACEOUS PENEPLAIN, CONTINENTAL SHELF AND LONG ISLAND SOUND

None of these unconsolidated materials cross Long Island Sound. It is, therefore, impossible for Long Island ground water to be derived from the streams of Connecticut as popular opinion on the island so widely holds. It is unnecessary to point out that the nature of the underlying rock is not such as to serve as a conduit for water and the most casual study of the shape of the ground water table on the island indicates that hydraulically any remote source of water supply is impossible. In other words, all the ground waters of Long Island originate from rain falling on the island itself.

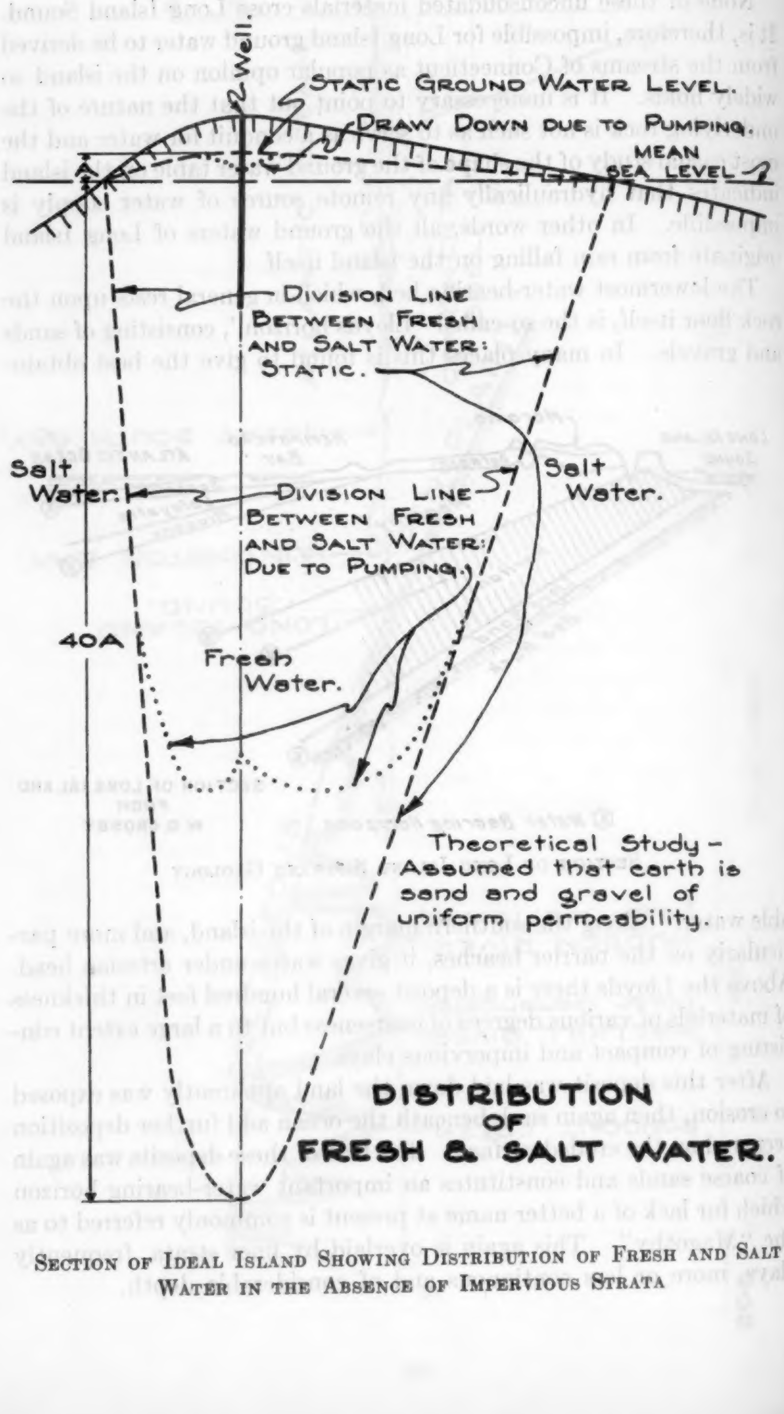
The lowermost water-bearing bed, which in general rests upon the rock floor itself, is the so-called "Lloyds horizon", consisting of sands and gravels. In many places this is found to give the best obtain-



SECTION OF LONG ISLAND SHOWING GEOLOGY

able water. Along the southern margin of the island, and more particularly on the barrier beaches, it gives water under artesian head. Above the Lloyds there is a deposit several hundred feet in thickness of materials of various degrees of coarseness but to a large extent consisting of compact and impervious clays.

After this deposit was laid down the land apparently was exposed to erosion, then again sank beneath the ocean and further deposition occurred on the eroded surface. The first of these deposits was again of coarse sands and constitutes an important water-bearing horizon which for lack of a better name at present is commonly referred to as the "Magothy". This again is overlaid by finer strata, frequently clays, more or less continuous and of considerable depth.



SECTION OF IDEAL ISLAND SHOWING DISTRIBUTION OF FRESH AND SALT WATER IN THE ABSENCE OF IMPERVIOUS STRATA

Just prior to the ice age it is assumed that the land was again exposed to the air and to erosion. On this eroded surface was deposited an accumulation of gravel, frequently of considerable thickness, commonly known as "Jameco" and which is an important source of water supply. One of the current theories is that this gravel was laid down by streams flowing from the front of the advancing ice sheet. In general it is covered by a clay blanket known as the "Gardiners" and on this are more recent deposits, largely of glacial nature. In general these are pervious up to the surface and are also water-bearing. For example, the majority of the wells in Brooklyn draw water from above the Gardiners clay, while a few of these wells and many of the New York City wells on the south shore penetrate to the Jameco.

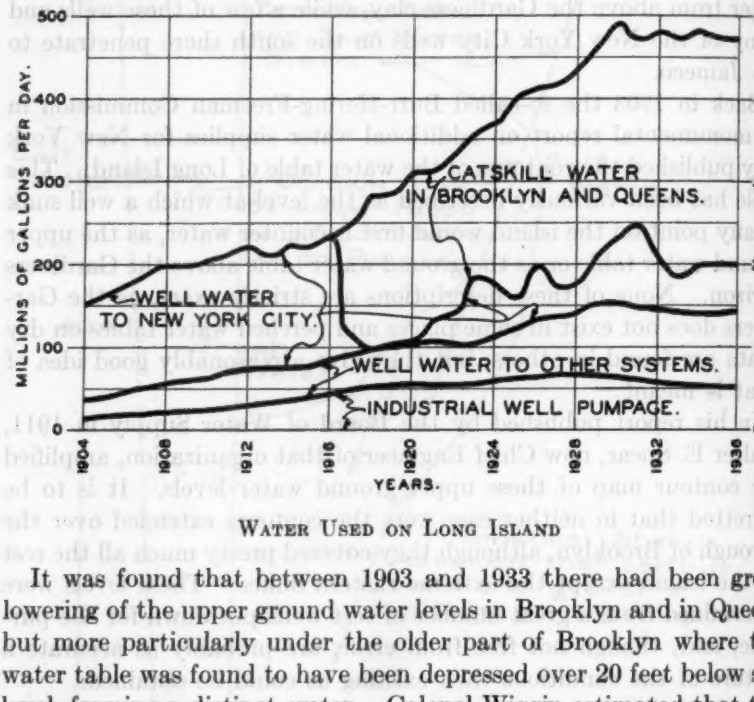
Back in 1903 the so-called Burr-Hering-Freeman Commission in its monumental report on additional water supplies for New York City published the contours of the water table of Long Island. This table has been variously described as the level at which a well sunk at any point on the island would first encounter water, as the upper ground water table or as the ground water table above the Gardiners horizon. None of these descriptions are strictly exact, as the Gardiners does not exist in some places and perched water tables on dry strata are found in others, but they give a reasonably good idea of what is meant.

In his report published by the Board of Water Supply in 1911, Walter E. Spear, now Chief Engineer of that organization, amplified the contour map of these upper ground water levels. It is to be regretted that in neither case were the contours extended over the borough of Brooklyn, although they covered pretty much all the rest of the island except the extreme eastern flukes. These levels were determined from a great number of test wells put down for the purpose, and, though not free from error, are probably as accurate a picture of the conditions then existing as could be obtained.

In 1933 the question arose as to whether after a lapse of thirty years the general ground water levels of the island had changed, particularly in view of the increase in surface drainage works and of pumpage. The matter was studied by William W. Brush, then Chief Engineer of the Department of Water Supply, Gas and Electricity of the City of New York, together with Thomas H. Wiggin and James F. Sanborn, Consulting Engineers. The study covered only Brooklyn and Queens. Data were obtained from existing wells

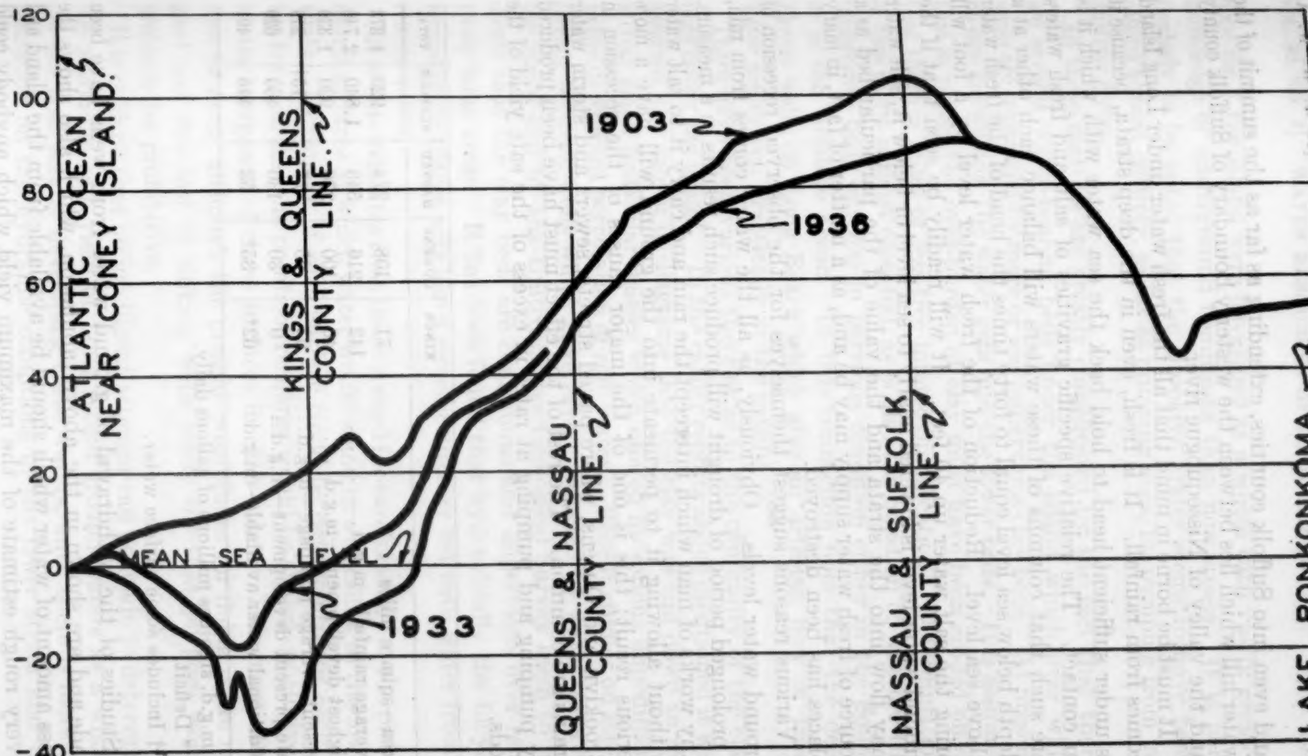
and such of the old test wells as were still available. Great concentrations of pumping, especially in Brooklyn, make such determination difficult and these results are less exact than the earlier ones. Later Colonel Wiggin reconstructed the probable ground water contours in Brooklyn as of 1903.

In 1936 the Water Power and Control Commission of the State of New York redetermined these ground water levels for the entire island. The results are less precise than those used for the other two and the data were lamentably meager, but it is believed to be generally representative of conditions at that time.



Water Used on Long Island

It was found that between 1903 and 1933 there had been great lowering of the upper ground water levels in Brooklyn and in Queens but more particularly under the older part of Brooklyn where the water table was found to have been depressed over 20 feet below sea level, forming a distinct crater. Colonel Wiggin estimated that the depletion of the ground water table in thirty years equalled in volume the capacity of Ashokan reservoir and that the recession of ground water levels at the point of maximum depression was taking place at the rate of approximately 15 inches a year. The 1936 results showed still greater depression in Brooklyn and, in fact, hardly anywhere in that borough did the ground water levels stand above sea level; and showed great recession of these levels in Queens, in Nassau



Upper Ground Water Surface on Long Island in 1903

and even into Suffolk counties, extending as far as the summit of the water hill which lies between the westerly boundary of Suffolk county and the valley of Nissequogue river.

It must be borne in mind that all the fresh water under Long Island comes from rainfall. It is fresh, even in the deep strata, because it is under sufficient head to hold back the sea water with which it is in contact. The relative specific gravities of salt and fresh waters are such that columns of these waters will balance each other at a depth below sea level equal to forty times the head of the fresh water above sea level. Reduction of the fresh water level by a foot will bring the salt water up 40 feet. It will readily be seen that if the ground water level is lowered nearly to sea level or below it, salt water may flow into the strata and the value of the particular bed as a source of fresh water supply may be and, as a matter of fact, in many places has been destroyed.

Various reasons suggest themselves for the observed recession of ground water levels. Obviously, as all the water comes from rain, a prolonged period of drought will produce such results in a measure. Any works of man which intercept the rain and carry it to salt water without allowing it to permeate into the ground will have a more serious result; this is one of the major causes of the recession in Brooklyn and Queens, where paved streets, sewers and storm water drains are common. The rest of the effect must have been produced by pumping and pumping at rates in excess of the safe yield of the beds.

	KINGS	QUEENS	NASSAU	SUFFOLK	TOTAL
Area—square miles	71	108	274	920	1,373
Average rainfall—m.g.d	142	216	548	1,840	2,746
Highest development—m.g.d	40	100	270	920	1,330
Present average pumpage—m.g.d	62	65	77†	15†	219
Safe present development—m.g.d	0	30	130	460	620
Additional water available—m.g.d	62*	35*	53	445	401

m.g.d. signifies millions of gallons daily.

* Deficit.

† Includes some surface water.

Studies of the withdrawal of ground water from wells have been made and are shown in the above tabulation, which also shows the gross amount of water which should be available from the island and a very rough estimate of the maximum yield which anybody could

hope for if the island were developed as a whole with vastly greater knowledge of underground conditions than now exists. It is particularly to be noted that the Brooklyn crater seems to have been caused almost entirely, as far as pumping goes, by pumping from industrial wells.

All these matters are greatly complicated by the fact that there are several water-bearing beds under the island which over wide areas are separated by more or less impervious clay beds. At present no one knows how the water gets into the lower beds. It is assumed that in places the over-burden of clay must have been eroded off so that there is more or less free intercommunication. Determination of this point is most essential, as is also the question of whether the underlying beds outcrop in pervious condition either in the Sound or in the Atlantic ocean. In this connection note that the deep Lloyds wells on Long Beach which give an artesian flow of fresh water are driven practically in the ocean.

There have been various theories as to the continuity of the clay beds under the island. In the earlier reports above mentioned it was assumed and shown in diagrams that the clay was laid down in relatively small lenticular masses which offered no serious impediment to the downward percolation of rain water. Recent studies on interference between wells which have been conducted by water users on the island and by the United States Geological Survey seem to indicate that the clay beds are continuous and impervious over relatively large areas. It has been found that hydraulically the Lloyds formation in places acts like a closed container fed with water from a remote point.

All of this indicates that there is need for careful study of the piezometric surfaces at which water would stand in wells sunk to the lower strata. Obviously, if such surface could be determined for each of the lower strata, the points of recharge would be shown conclusively by the mergance of these surfaces in each other. This must some time be done, although the present possibilities for doing it are not good and the cost of sinking wells solely for that purpose would probably be prohibitive.

It is evident that no intelligent attempt can be made to determine the maximum safe yield of Long Island ground waters as a whole, nor the best way of developing these waters, until there is more information on the hydraulic conditions in the lower strata and the origin of the water in them.

THE PRESENT CONDITION OF NEW YORK CITY'S LONG ISLAND SOURCES OF WATER SUPPLY

By Wm. F. Laase

Before entering upon the subject of the present condition of the City's Long Island supply, it may be of interest to discuss briefly the sources from which New York secures its entire supply.

The principal supply comes from up-state sources, namely: The Croton, Bronx and Byram watersheds east of the Hudson River; and the Esopus and Schoharie watersheds west of the Hudson River. These two are surface supplies. In addition two other sources of supply are available—one on Long Island, and the other on Staten Island, both of which are practically 100 per cent sub-surface.

The safe dependable yield of all the above-mentioned sources of supply is estimated to be about 1000 m.g.d., which represents the yield of the watersheds for a minimum rainfall-year.

The average consumption from all municipal sources was 932 m.g.d. in 1936. The indicated yearly increase in demand is estimated at 20 m.g.d., so that the demand is closely approaching the dependable yield.

The city, however, proposes to continue more intensively the reduction of waste—both inside and outside of buildings and possibly extend metering in order to reduce consumption and thus conserve the supply until the advent of the first installment of Delaware water.

The estimated safe yield of 1000 m.g.d. includes an item of 139 m.g.d. of developed yield secured mainly from the sands of Long Island, and it is this source together with other pertinent data which the speaker will briefly outline.

The city of New York has confined its water supply system to the counties of Kings and Queens and to the southerly portion of the county of Nassau. In the former two counties there are also two major private water companies supplying water from sub-surface

A discussion presented by Wm. F. Laase (Borough of Queens Engineer, Bureau of Water Supply, City of New York) at the joint session of the New York and New Jersey sections, December 29, 1937.

sources within three franchise areas, and numerous industrial concerns have constructed wells for their own commercial needs. In Nassau County there are many villages which have developed their own sub-surface water supply system, and several private water companies, which have likewise developed sub-surface water supplies. There are comparatively few industrial well-developments in Nassau County.

The entire underground water supply is a sluggish stream moving slowly and wasting into the salt water at or beyond the shore lines of the island, continually augmented by the rainfall.

The water supply of the island is divided into two parts—one is the storage and the other is the recharge which, in other words, is the replenishment from rainfall. Safe yield is here used to mean the recharge; the recharge includes percolation and stream flow. It is diminished by paved streets, construction of sewers, and by increased population on the watershed. In the easterly part of Nassau county, a safe yield can be secured in excess of 1 m.g.d. for continuous operation, and as high as 1.25 m.g.d. per square mile for intermittent operation, by a complete development of all sub-surface sources while in those parts of Brooklyn where the pervious area is 30 percent of the total area, the safe yield per square mile of area is considerably less than those figures.

The temptation to exceed the safe yield has existed and will continue to exist, if not checked. The safe yield has been exceeded in Brooklyn, the stored water in the sands has been drawn out and a great crater has been formed in the underground reservoir, the deepest part of which is 30 feet below sea-level. Where the lip of this crater reaches the shore at salt water, the reversal of hydraulic gradient through the sand causes the salt water to flow into the crater, salting individual wells, and in some cases, destroying the usefulness of the source of supply.

As stated, in the borough of Brooklyn, the safe yield per unit of area has been exceeded, and in the southwesterly part of Queens the safe yield has been exceeded but not as extensively at the present time as in Brooklyn. In Nassau county, there is still considerable margin before the safe yield is reached.

In the county of Nassau, south of the ground-water divide, the city's existing development, consisting mainly of the tubular gang-well-type, will safely yield about 77 m.g.d. if continuously operated. Within this area, other municipalities and private water companies

have well-developments from which a supply of about 30 m.g.d. is secured from a total development of about 75 m.g.d. The combined safe yield of the city's plants and the pumpage from other wells amounts to 107 m.g.d. from a watershed area of 136 square miles; or at the rate of about 0.8 m.g.d. per square mile of area. Since practically all city stations are located near tide water and down-stream from said other municipalities and private companies, the water pumped by the city is that which would normally go to waste.

In the borough of Queens, along the southerly portion thereof, the city maintains seven driven-well stations. These stations are close to tide water and down-stream of the underflow, with an estimated yield at this time amounting to 31 m.g.d. and an actual pumpage of 12.073 m.g.d. in 1936. Within this area there are two major private water companies—one in Jamaica and one in Woodhaven, which have a total estimated well capacity of 82 m.g.d., and in 1936 the pumpage averaged 33 m.g.d. from both plants. In addition, industrial wells with an estimated development in excess of 21 m.g.d. have pumped about 14.5 m.g.d.

In the northerly part of Queens the city has a sub-surface development of 21 m.g.d. with pumpage of 10.4 m.g.d. in 1936. Within this area, and about six years ago, the city constructed seven large diameter wells, electrically operated, with a total capacity of 11.5 m.g.d., and approval of the construction and operation of said wells is now pending before the Water Power and Control Commission.

The city has three pumping stations of the tubular gang-well type, in the southerly part of Brooklyn, with a total present capacity of 11 m.g.d. They have not been operated for several years past and are held in reserve to be used only in emergencies.

The Flatbush plant of New York Water Service Corp., located approximately in the center of the Borough of Brooklyn, secures a supply of 26 m.g.d., to meet its demand, from about 30 wells of large diameter, electrically operated. The Woodhaven plant of the New York Water Service Corporation is located in the extreme southwesterly part of the Borough of Queens. It consists of five stations, four of which are electrically operated, and one steam plant located in the southerly part of its territory at Aqueduct. The maximum capacity from this latter plant is 7 m.g.d. or more, but is operated at the rate of approximately 3 m.g.d., except for peak demands. The consumption demand averages 8 m.g.d. from the entire plant. The Jamaica Water Supply Company serves the southeasterly portion of

Queens County and part of the west-central portion in Nassau County. This company operates 41 wells of large diameter located within its franchise area to satisfy a demand of approximately 28 m.g.d.

New York City is now constructing its new Delaware system, and it is estimated that the first installment of water from this source will be available in about six or seven years. In the meantime it may become necessary to operate the stations on Long Island depending of course upon the ability of the up-state sources to supply the demand. Upon completion of this new source of supply, it is anticipated that practically all of the city's said Long Island sources will not be operated but held in reserve for emergency use.

THE QUALITY OF THE UNDERGROUND WATERS OF LONG ISLAND

By George D. Norcom

During the past few years there has been an increased interest in the water supply of Long Island. With the exception of Sag Harbor,* all of the communities in Nassau and Suffolk Counties secure their water from underground sources and it is probable that this also applies to practically all of the rural inhabitants. The New York Legislative Manual gives the populations of these counties in 1930 as follows: Nassau, 303,053; Suffolk, 161,055; Kings, 2,560,401; Queens, 1,079,129. Kings and Queens Counties are within the limits of the City of New York and their inhabitants are largely supplied with surface water from the Catskills, but a part of this population is supplied with ground water from city owned wells on Long Island and by several private companies, the largest of which are the New York Water Service Corporation and the Jamaica Water Supply Company.

GEOLOGIC CONDITIONS

For the student who is interested in the geology of Long Island and its relation to water supply, a wealth of material will be found in the work of John R. Freeman (4), Myron L. Fuller (13), Burr, Hering and Freeman (5), and Walter E. Spear (12). The geologic factors which affect the water supply of Long Island are summarized in a single paper jointly written by Veatch, Slichter, Bowman, Crosby and Horton (6), as follows:

"1. Above a rock floor which underlies the island at a greater or less depth. . . . Long Island is composed of a nucleus of Cretaceous beds. These are for the most part sand, but contain some discontinuous clay masses, and dip, except

A paper by George D. Norcom, Consulting Chemist of New York City, presented at the meeting of the New York Section held in Schenectady, October 1, 1937. For references to literature, see consolidated list on page 324.

* Sag Harbor will shortly replace its surface sources with a well supply and iron removal.

for minor disturbances produced by ice thrust, regularly southward."

"2. Beds of glacial gravel deposited in an early ice advance surround this nucleus, except in a portion of the southern side of the island, which the older hill land protected from direct currents and in other places where they have been removed by subsequent erosion. This formation, which has been called the Jameco gravel, is particularly well developed near the western end of the island, where it has partially filled a deep, broad valley in the older beds.

"3. Over this gravel and around the edge of the Cretaceous beds is a layer of blue clay, the Sankaty—a deposit somewhat similar to, but of greater extent than the coastal marsh deposits of today, and at present situated from 50 to 100 feet below them.

"4. Covering both the nucleus of Cretaceous beds and the younger blue clay, with its underlying early glacial gravel, are deposits of more recent ice advances—the Tisbury and Wisconsin. These are, for the most part, sand and gravels, though here and there are local beds of clayey material . . ."

The more important results of these geologic conditions are:

"1. The rain water sinks directly into the very porous surface gravels and produces, therefore, practically no run-off, except that supplied by springs. Since all streams are spring fed there is great difficulty in determining the exact limits of the watersheds, which depend on the relief of the ground-water table and only indirectly on the shape of the surface.

"2. As a greater portion of the water of the island is under ground, and as the 25 to 30 per cent which normally returns to the surface is exposed for but a relatively short distance, the percentage of the total rainfall lost by evaporation is abnormally small and the yield of this watershed, could all the water be economically obtained, would, therefore, be larger per square mile than in any adjoining areas.

"3. As there is no uniform "blue-clay floor," or other extensive geologic barrier, a portion of the ground water passes coastward in the upper gravels and another portion, and by no means a negligible one, sinks into the Jameco and Cretaceous

sands and finally escapes in the form of suboceanic springs. This transmission of water is one of the more important factors of the underground conditions of Long Island. There is no geologic reason why a relatively important portion of the rainfall should "not pass seaward in the beds below the surface gravel, and that this occurs has been proved by the many deep wells on the island and by the work of Prof. Charles S. Slichter, who has shown that there is a greater velocity beneath the bed of blue clay than in the surface gravel . . ."

WATER SUPPLY

The water supply situation on Long Island has very recently been described in a vigorous manner by Mr. Russell Suter (23), Executive Engineer of the State Water Power and Control Commission. In his report on the Water Supplies of Long Island, Mr. Suter points out that the highest development of the entire water resources of the island would yield approximately 1330 m.g.d., although the average pumpage at present is only 219 m.g.d. Unfortunately, over half of this pumpage is concentrated in the boroughs of Kings and Queens. In summarizing his report Mr. Suter makes the following recommendations:

"Clothe some authority with the necessary regulative powers.

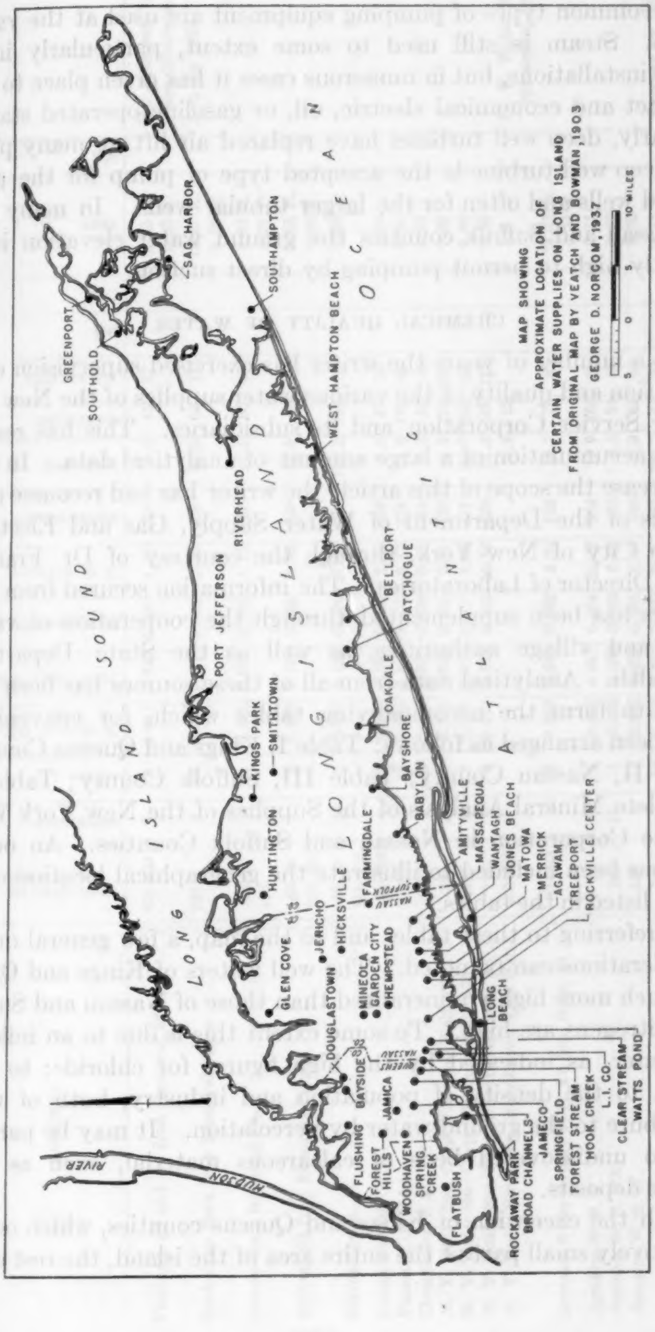
"Stop or curtail pumping in depleted areas until they have been replenished.

"Arrange for the supply of enough water to carry these areas during the period.

"Redevelop and continue development under rigid control."

WELLS AND PUMPING EQUIPMENT

The most common type of wells used on Long Island are simple tubular steel wells equipped with strainers and the well known gravel packed wells with double casing and strainers. For the most part, the first type is limited to wells yielding 1 m.g.d. or less, but some of the second type yield upwards of 3 m.g.d. Many of the earlier installations consist of a considerable number of tubular wells connected to a common suction line. There are a few dug wells still in use. The City of New York operates two infiltration galleries, the Wantagh and Massapequa, consisting of a collecting system several miles long laid in and east-west direction at an average depth of perhaps 30 ft.


MAP SHOWING
APPROXIMATE LOCATION OF
CERTAIN WATER SUPPLIES ON LONG ISLAND
FROM ORIGINAL MAP BY VEATCH AND BOWMAN 1903
GEORGE D. NORCOM 1937
5 0 5 10 MILES
HUDSON RIVER
GREENPORT
SOUTHOLD
SAG HARBOR
SOUTHAMPTON
WEST HAMPTON BEACH
RIVERHEAD
PORT JEFFERSON
BELLPORT
PATCHOGUE
OAKDALE
SMITHTOWN
KINGS PARK
BAYSHORE
BABYLON
HUNTINGTON
FARMINGDALE
AMITYVILLE
MASSAPEQUA
WANTAGH
JONES BEACH
MATOWA
MERRICK
AGAWAM
FREEPORT
ROCKVILLE CENTER
SUFFOLK
NASSAU
JERICHO
HICKSVILLE
GLEN COVE
MINEOLA
GARDEN CITY
HEMPSTEAD
DOUGLASTON
BAYSIDE
LONG BEACH
QUEENS
FLUSHING
FOREST HILLS
JAMAICA
WOODHAVEN
SPRING CREEK
FLATBUSH
ROCKAWAY PARK
BROAD CHANNELS
JAMECO
SPRINGFIELD
FOREST STREAM
HOOK CREEK
L. I. CO.
CLEAR STREAM
WATTS POND

All common types of pumping equipment are used at the various plants. Steam is still used to some extent, particularly in the larger installations, but in numerous cases it has given place to more compact and economical electric, oil, or gasoline operated stations. Similarly, deep well turbines have replaced air lift at many plants. The deep well turbine is the accepted type of pump for the gravel packed wells and often for the larger tubular wells. In many parts of Nassau and Suffolk counties the ground water elevation is sufficiently high to permit pumping by direct suction.

CHEMICAL QUALITY OF WATER

For a number of years the writer has exercised supervision of the sanitation and quality of the various water supplies of the New York Water Service Corporation and its subsidiaries. This has resulted in the accumulation of a large amount of analytical data. In order to increase the scope of this article the writer has had recourse to the records of the Department of Water Supply, Gas and Electricity of the City of New York, through the courtesy of Dr. Frank E. Hale, Director of Laboratories. The information secured from these sources has been supplemented through the cooperation of various town and village authorities, as well as the State Department of Health. Analytical data from all of these sources has been combined to form the accompanying tables which, for convenience, have been arranged as follows: Table I, Kings and Queens Counties; Table II, Nassau County; Table III, Suffolk County; Table IV, Complete Mineral Analysis of the Supplies of the New York Water Service Corporation in Nassau and Suffolk Counties. An outline map has been included to illustrate the geographical location of the places listed in the tables.

By referring to these tables and to the map, a few general quality considerations can be noted. The well waters of Kings and Queens are much more highly mineralized than those of Nassau and Suffolk. The nitrogens are high. To some extent this is due to an inflow of sea water, as indicated by the high figures for chloride; to some extent to the density of population and industry, both of which contribute to the ground water by percolation. It may be partially due to undiscovered beds of calcareous material, such as large marine deposits.

With the exception of Kings and Queens counties, which occupy a relatively small part of the entire area of the island, the rest of the

TABLE I

Results of analysis of well waters in Kings and Queens, New York City. Averages for 1935 unless otherwise indicated

Chemical results in p.p.m. Depths measured from ground surface

LOCATION	APPROXIMATE DEPTH, FEET	TURBIDITY	COLOR	N IN ALB. NH_3	N IN FREE NH_3	N IN NITRITE	N IN NITRATE	TOTAL SOLIDS	CHLORIDE	HARDNESS	ALKALINITY	pH	CO_2	IRON	Mn	
Flushing #1 and #5 Iron Removal Plant	421–455	1	2	0.041	0.028	0.001	1.43	99	9.4	41	27			3.43 R.		Mt. Prospect Lab. unless otherwise stated
														0.23 F.		
Rockaway Park Iron Removal Plant	728	2	10	0.024	0.073	0.001	0.05	169	63.0	34	11			12.0 R.		Ave. for 1933
														0.58 F.		
Jameco Iron Removal Plant	40–60	1	1	0.031	0.015	0.000	1.31	167	16.5	80	47			4.43 R.		
	170													0.23 F.		
Springfield Iron Removal Plant	40–60	1	1	0.032	0.127	0.003	0.95	140	28.4	44	5			5.65 R.		
	127–207													0.26 F.		
Spring Creek	60–70	2	6	0.057	0.165	0.006	5.06	810	188.2	365	165			0.68		
	116–166															
Forest Stream	55–100	4	3	0.064	0.592	0.004	1.43	106	9.3	37	10			1.03		
Forest Hills E 1A	92	2	10	0.041	0.034	0.005	0.37	278	14.6	185	140			0.62		
Douglaston E 3	523	0	0	0.027	0.017	0.004	0.43	53	5.6	21	14			0.05		
N. Y. Water Ser. Corp. Flatbush Well #17	301	1	1	0.285	0.640	0.002	0.14	190	11.9	119	106			0.23		
N. Y. Water Ser. Corp. Flatbush Well #30	162	0	0	0.027	0.015	0.011	8.53	417	30.7	286	153			0.09		
N. Y. Water Ser. Corp. Woodhaven Well #5	114	0	0	0.027	0.012	0.002	10.54	460	34.8	284	177			0.15		
N. Y. Water Ser. Corp. Woodhaven Test Well	500–585								8.4	22				5.7		N. Y. Water Ser. Lab. November 1934
Jamaica Water Supply P. S. #6 Iron Rem. Pl.	51–573	1	3	0.025	0.042	0.002	2.94	184	16.7	78	25			*3.23 R.		
														0.34 F.		
Jamaica W. S. 4	80	0	1	0.033	0.017	0.024	12.17	334	19.9	162	68			0.13		
Jamaica W. S. 17A	286	15	5	0.033	0.052	0.000	0.03	160	6.5	91	87			0.97		
Jamaica W. S. 17	560	5	17	0.025	0.027	0.001	0.07	160	5.3	61	56			0.70		
Broad Channel Corp.	720	7	10	0.028	0.036	0.002	0.07	265	106.7	43	15			16.78 R.		Average for 1933
														1.46 F.		

* Approximate. R., raw. F., filtered.

TABLE II

Results of analysis of well waters in Nassau County, 1935 yearly average results unless otherwise indicated

Chemical results in p.p.m. Depths measured from ground surface

LOCATION	APPROXIMATE DEPTH, FEET	TURBIDITY	COLOR	N IN ALB. NH_3	N IN FREE NH_3	N IN NITRITE	N IN NITRATE	TOTAL SOLIDS	CHLORIDE	HARDNESS	ALKALINITY	pH	CO_2	Fe	Mn	
City of New York:																
Hook Creek	50–105	1	2	0.050	0.149	0.001	1.88	99	8.7	32.0	7.0			0.51		Mt. Prospect Lab.
Clear Stream Wells	38–54 300–425	1	1	0.027	0.035	0.000	3.34	110	7.6	34.0	6.0			0.56		Mt. Prospect Lab.
Watts Wells	60	1	1	0.058	0.430	0.003	4.02	136	19.0	57.0	8.0			0.30		Mt. Prospect Lab.
Agwam Wells	30–100	1	1	0.078	0.303	0.009	2.07	85	8.5	28.0	5.0			0.35		Mt. Prospect Lab.
Matowa Wells	30–150	3	3	0.050	0.098	0.022	0.20	79	3.2	10.0	1.0			1.80		Mt. Prospect Lab.
Wantagh Gallery	20–30	1	1	0.042	0.262	0.002	3.13	119	10.9	42.0	7.0			0.23		Mt. Prospect Lab.
Massapequa Gallery	20–30	1	1	0.037	0.053	0.000	1.00	75	7.3	29.0	12.0			0.23		Mt. Prospect Lab.
Municipalities:																
Rockville Centre #2	335	0	2	0.014	0.010	0.001	0.010	33	4.0	4.0	4.0	5.3	26.9	0.12		10/31/28 Pease
Freeport #1	535	2	0	0.006	0.028	0.001	0.020	25	3.8	5.0	2.0	5.2	23.0			5/23/29 Potts, S. Bd. H.
Long Beach #1	1,000	2	12	0.022	0.006	0.002	0.020	90	4.0	18.0	8.7	5.6	28.5	4.3		12/ 7/28 Pease
Jones Beach	1,034	0	5						10.0	0	37.0	6.0	33.0	0.8		1/30/33 L. I. Park Com.
Garden City #4	90	1	4	0.038	0.014	0.001	8.5	195	56.4	63.0	10.0	5.75	31.7	0.30		3/10/32 Pease
Garden City #6	375	7	18	0.040	0.032	0.003	0.80	58	9.4	8.0	8.0			0.75		Pease
Hicksville #3	158	4	9	0.054	0.030	0.002	2.4	24	5.8	11.0	3.0	5.75	7.4	0.08		4/16/31 Pease
Jerico #3	617	2	7	0.046	0.020	0.001	0.50	33	4.8	4.0	4.0	5.9	8.8	0.20		4/14/30 Pease
Hempstead #3	381	4	5	0.028	0.006	0.001	0.40	23	5.8	4.0	7.0	5.7	20.0	0.30		7/14/30 Pease
Mineola #2	366	4	1	0.002	0.002	0.002	1.00		4.6	11.1	5.0					7/18/27 St. Bd. H.
Private Water Cos.:																
L. I. Water Co., Valley Stream, Iron Rem. Pl.	35 135–195	1	3	0.042	0.014	0.001	0.05	64	4.3	29.0	23.0			1.95 R. 0.14 F.		Mt. Prospect Lab.
N. Y. Water Ser. Corp., Merrick	40–45	1	0						10.3	36.0	4.4	5.4	21.2	0.06	0.10	1936 average, N. Y. W. S. Corp. Lab.
N. Y. Water Ser. Corp., Massapequa #1	48	0	1						6.6	21.4	12.8	6.1	10.5	0.03	0.05	
N. Y. Water Ser. Corp., Glen Cove	55–281	0	1						6.2	24.7	13.8	6.1	11.8	0.01	Trace	

TABLE III

The results of analysis of well waters in Suffolk County, 1936 yearly average results unless otherwise indicated

Chemical results in p.p.m. Depths measured from ground surface

LOCATION	APPROXIMATE DEPTH, FEET	TURBIDITY	COLOR	N IN ALB. NH_3	N IN FREE NH_3	N IN NITRITE	N IN NITRATE	TOTAL SOLIDS	CHLORIDE	HARDNESS	ALKALINITY	pH	CO_2	Fe	Mn	
Municipal Plants:																
Riverhead—New Well	100	Trace	0	0.012	0.032	0.001	0.020		5.6	29.9	30.0			0.2		10/22/30* Bd. of H.
Greenport	55	Trace	0	0.006	0.002	0.001	1.12		49.8	39.0						2/ 4/33* Bd. of H.
Private Water Cos.:																
South Bay Consol. Water Co.:																
Amityville	50	1	1						8.1	24.6	9.7	6.2	15.1	0.03	0.09	N. Y. W. S. Lab.
Bay Shore	50	1	4						6.8	21.8	7.7	5.8	14.8	0.03	0.21	N. Y. W. S. Lab.
Bellport	45	0	1						7.5	17.8	6.0	6.0	8.2	0.03	Trace	N. Y. W. S. Lab.
Kings Park (Lower Pump Station)	150	1	2						5.8	10.7	6.3	5.8	12.1	0.08	0	N. Y. W. S. Lab.
Oakdale #1	90	2	2						5.7	20.0	14.3	6.3	8.8	0.07	0	N. Y. W. S. Lab.
Patchogue	60	7	24						9.8	19.0	11.6	6.1	13.6	0.80	0.13	N. Y. W. S. Lab.
Port Jefferson	60	1	1						4.7	15.5	14.3	6.4	7.1	0.01	0	N. Y. W. S. Lab.
Smithtown (Elec.)	145	3	3						4.0	24.0	24.8	6.3	14.8	0.14	0.06	N. Y. W. S. Lab.
Southampton #1	95	0	0						15.5	46.9	6.6	5.9	12.4	0.02	Trace	N. Y. W. S. Lab.
Westhampton	30-40	0	1						7.3	12.0	6.5	6.1	7.5	0.02	0.02	N. Y. W. S. Lab.
New York Water Ser. Corp.:																
Babylon	60	0	1						4.6	11.6	5.9	5.7	14.5	0.16	0.07	N. Y. W. S. Lab.
Huntington (Deep #1)	540-590	0	1						4.3	26.0	22.4	6.7	4.9	0	0	N. Y. W. S. Lab.
Sag Harbor Test Well	113								11.0	41.2	22.0	6.3	23.5	4.5		4/9/31* N. Y. W. S. Lab.
North Fork Water Co., Southold	50	Trace	4	0.042	0.052	0.036	5.20		25.0	45.7	23.0			0.04		10/8/29* Bd. of H.

* Results of a single test.

TABLE IV

Complete mineral analysis of the water supplies owned by the New York Water S. Corp. on the north and south shores of L. I.

All results expressed in p.p.m.

WATER SUPPLY	DATE OF SAMPLE	pH	FREE CO_2	TOTAL ALKALI, $CaCO_3$	TOTAL HARDNESS, $CaCO_3$		CALCIUM, Ca	MAGNESIUM, Mg	SODIUM (BY CALC.), Na	IRON, Fe	MANGANESE, Mn	CARBONATES, CO_3	BICARBONATES, HCO_3	SULPHATES, SO_4	CHLORIDES, Cl	NITRATES, NO_3	SILICA, SiO_2	NON-VOL. RES.	TOTAL SOLIDS		HYPOTHETICAL COMBINATIONS OF DRY SOLIDS								
					Soap	Anal.													By wt.	By anal.	$CaCO_3$	$CaSO_4$	$MgCO_3$	$MgSO_4$	$MgCl_2$	Na_2CO_3	Na_2SO_4	NaCl	$NaNO_3$
Amityville, P. S.	Feb. 8, 1935	5.8	12.0	4.0	11.0	9.9	2.0	1.2	4.8	0.02	Tr.	0	4.9	4.9	6.5	2.7	7.4	1.8	32.0	33.7	4.0	1.4		4.9	0.8			9.7	3.7
Babylon, P. S.	Feb. 8, 1935	5.7	16.0	6.0	8.0	7.9	2.0	0.7	6.1	0.08	0.05	0	7.3	4.8	7.0	0.4	9.2	1.4	33.1	35.2	5.0		0.9	2.2			4.4	11.5	0.6
Bay Shore, P. S.	May 20, 1935	5.6	18.5	5.0	22.0	20.9	4.9	2.1	9.0	0.04	0.24	0	6.1	12.1	9.0	12.5	8.4	0.1	54.0	61.1	5.0	9.9		6.5	3.1			11.0	17.1
Bellport, P. S.	Apr. 29, 1935	6.8	10.5	6.5	15.0	18.3	4.2	1.9	7.0	0.07	0	0	7.9	8.5	10.0	5.0	6.8	0.7	47.0	48.0	6.5	5.4		6.0	2.8			13.0	6.8
Kings' Park-Upper, P. S.	Feb. 25, 1935	5.7	12.5	7.0	22.0	19.1	4.2	2.1	6.1	0.04	0.03	0	8.5	6.3	8.0	9.3	8.8	0.2	51.8	49.2	7.0	4.7		3.7	5.3			6.7	12.8
Massapequa, P. S.	Apr. 29, 1935	5.9	14.0	12.0	18.0	19.0	4.0	2.2	7.0	0.07	0.06	0	14.6	7.2	8.5	3.5	9.2	0.3	47.6	49.1	10.0		1.7	8.4			0.7	14.0	4.8
Merrick, P. S.	Feb. 8, 1935	5.6	23.0	5.0	34.0	35.6	10.1	2.5	11.0	0.02	0	0	6.1	22.5	12.0	17.5	8.7	0.7	90.0	88.0	5.0	27.5		3.9	6.7			11.5	24.0
Oakdale-Well, 1	Jan. 28, 1935	6.1	10.0	13.5	17.5	18.9	4.9	1.6	5.0	0.02	Tr.	0	16.5	4.6	7.5	0.9	11.1	0.9	44.8	44.6	12.3		1.1	5.8	0.5			11.7	1.2
Patchogue, P. S.	May 20, 1935	5.7	16.5	9.5	18.0	20.4	4.7	2.1	7.8	0.60	0.11	0	11.6	8.5	9.5	7.0	10.8	0.8	56.1	56.9	9.5	3.0		8.0	1.9			13.3	9.6
Port Jefferson, P. S.	Jan. 28, 1935	6.3	7.0	14.0	12.0	12.3	3.1	1.1	6.5	0	0	0	17.1	2.1	7.0	0.5	13.3	1.4	44.0	43.4	7.7		3.9			1.8	3.1	11.5	0.7
Sag Harbor, P. S.	Feb. 11, 1935	6.0	5.0	11.0	16.0	16.4	3.6	1.8	7.2	0.25	0	0	13.4	4.5	11.5	0.2	8.4	0.7	50.7	44.5	9.0		1.7	5.6	0.7			18.1	0.3
Smithtown, Diesel Eng. W. Air-Lift	Feb. 25, 1935	6.7	5.0	24.0	26.0	24.7	5.6	2.6	5.8	0.22	0.07	0	29.3	2.6	7.0	0.9	17.6	0.8	56.7	57.3	14.0		8.5	0.8			2.9	11.5	1.2
Southampton Well, 1	Feb. 11, 1935	5.9	12.0	7.0	47.0	47.1	11.9	4.2	12.3	Tr.	0	0	8.5	29.5	17.5	14.0	7.3	0.7	99.2	101.6	7.0	30.9		9.6	8.9			18.0	19.2
Southampton Well, 2	Feb. 18, 1935	5.9	11.0	9.5	48.0	46.4	11.3	4.4	12.1	0.04	0	0	11.6	25.3	19.0	12.4	12.2	0.5	101.0	102.9	9.5	25.4		9.2	10.0			19.1	17.0
Westhampton, P. S.	Apr. 29, 1935	5.8	9.0	10.5	9.0	12.1	1.7	1.9	7.8	0.06	0	0	12.8	5.5	9.0	0.2	5.9	0.6	34.1	38.9	4.3		5.2	1.9			5.8	14.8	0.3

well waters are generally soft, low in alkalinity, total solids, and high in free carbon dioxide, marking them as exceptionally corrosive to metals. Nitrogenous material is notably higher in the shallow wells than in the deep wells.

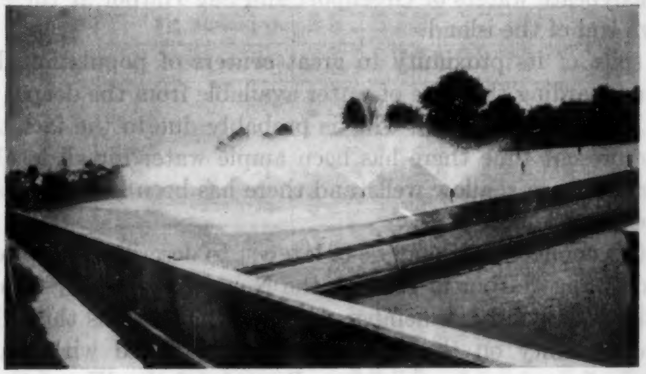
A third consideration of general interest is the distribution of iron and manganese. It would appear that two general classes of water should be noted in this regard: namely, iron and manganese of shallow swamp origin, and iron from the deeper geologic formations. Experience has shown that wells located along the stream valleys or in bogs overlain with sand, particularly on the south shore, deliver water containing up to 1.0 p.p.m. of iron and appreciable quantities of manganese (Patchogue and Bay Shore). In the second class are those deeper wells located in a belt beginning at Flushing, which widens as it extends south and east to include Rockaway Park and Jones Beach. In these waters the iron content runs from 1.0 p.p.m. to 16.8 p.p.m. and in many cases iron removal is necessary (Jamaica, Jameco and Springfield). Shallow wells located in this belt are generally lower in iron than deep wells. The location of this iron-bearing stratum coincides rather closely with that of the so-called "Sound River" valley. To this second class must be added the chalybeate waters of Greenport and Sag Harbor at the extreme eastern end of the island.

In spite of its proximity to great centers of population, little is known regarding the type of water available from the deeper formations in Suffolk County. This is probably due to the fact that up to the present time there has been ample water for all local needs obtainable from shallow wells and there has been little necessity for deep exploration.

In this connection it may be of interest to describe a deep test well drilled at Sag Harbor in 1931 by the New York Water Service Corporation. It will be remembered that Sag Harbor is the only sizeable community on the island which is supplied with water exclusively from a surface source. Records of the Water Company show that several shallow wells had been constructed in the past, all of which were later abandoned on account of the iron content. The test well was driven to a total depth of 540 ft. below the ground surface. For a depth of 275 ft., water-bearing sand and gravel were encountered, but samples of water taken at several points showed 4 to 5 p.p.m. iron. Between 275 and 475 ft., clay and mixtures of clay and sand were found. Below 475 ft. the well penetrated a

water-bearing sand, but upon analysis the water showed a chloride of 350 and hardness of 360, indicating sea water contamination. The results were quite similar to those secured in the case of a deep well at Greenport, where salt water was found from a depth of 255 to 555 ft., followed by clay formations and sand streaks terminating with rock at 670 ft.

WATER WORKS—HEMPSTEAD, N. Y.

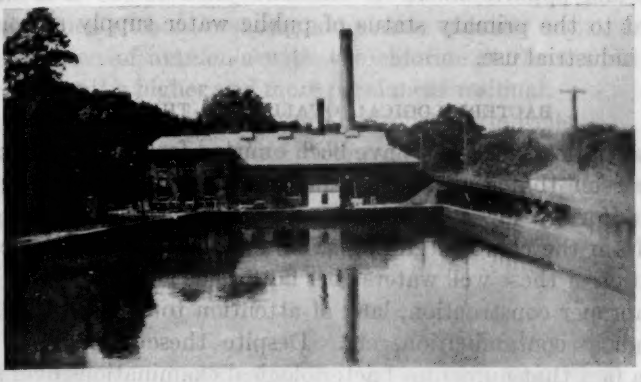


AERATION AT HEMPSTEAD

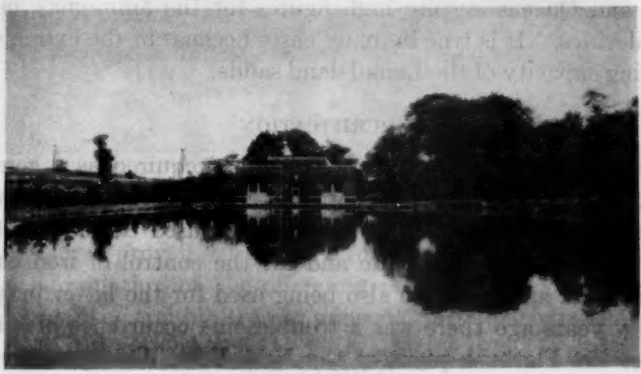
INTRUSIONS OF SEA WATER

It has been known for many years that overpumpage of the wells on Long Island would result in the intrusion of sea water. Records of the Department of Water Supply, Gas and Electricity of New York indicate that high chlorides have occurred in several of the south shore plants to such an extent as to require curtailment

and perhaps complete cessation of pumping. Similarly, a considerable number of privately owned wells have been affected. This is to be expected in view of the geological conditions previously described, because the underground water flowing toward the sea establishes a gradient which is governed by the resistance of the



PUMP STATION WITH SLOW SAND FILTER IN FOREGROUND
LONG ISLAND WATER CO., VALLEY STREAM



FLUSHING IRON REMOVAL PLANT, NEW YORK CITY

sand and the fresh water head. Extensive lowering of the ground water table by pumping decreases the available fresh water head, and sea water tends to diffuse inland. When the fresh water head has been lowered sufficiently, the wells deliver increasingly saline water. Once this condition has been established it takes a long time, measurable in years, for flow conditions to be restored to normal,

even after the pumping of the wells has stopped. When the lowering of the ground water has occurred as the result of overpumpage by a great number of wells owned by municipal, private, and industrial interests, as in Kings and Queens, the problem of control is very complicated. Obviously, what is needed is a scientific curtailment and apportionment of the safe yield of the area with due regard to the primary status of public water supply as contrasted with industrial use.

BACTERIOLOGICAL QUALITY OF THE WATER

Bacteriological results have been omitted from the tabulations for the reason that the natural underground waters of Long Island are uniformly low in numbers of bacteria and normally entirely free from the coliform group. This statement does not mean that pollution of these well waters does not or has not occurred as a result of improper construction, lack of attention to sanitary precautions, secondary contamination, etc. Despite these man made defects it is a fact that numerous bacteriological examinations over a period of years, from properly developed sources all over the island, attest the natural purity of the underground supply. This is true even in Kings and Queens despite high figures for the ammonias, nitrates, and chlorides. It is true in many cases because of the extraordinary purifying capacity of the Long Island sands.

PURIFICATION

Obviously chlorine treatment is seldom required as a germicidal agent, but it is used at some plants as a precautionary measure against possibility of pollution. It is also used extensively for the removal of hydrogen sulphide and for the control of iron bacteria. Chlorine and ammonia are also being used for the latter purpose.

A few years ago there was a troublesome occurrence of iron bacteria at the Flatbush plant of the New York Water Service Corp. which supplies about 26 m.g.d. of well water. Large sections of the distribution system became infested with particles of whitish to brown flocculent and fibrous particles which were found to contain luxuriant growths of iron bacteria when examined microscopically. The predominating organism was Crenothrix. A survey of all of the wells was undertaken and it was finally determined that most of the trouble originated in a group of deep wells installed between 1929 and 1931, although the organisms were also present in a number of the older shallow wells.

Remedial measures were planned to control the organisms at the source, insofar as possible, and to clean up the distribution system later. To this end the following steps were taken in the order named:

1. Application of chlorine to all water pumped from the infected wells so as to maintain the maximum residual which could be maintained without creating complaints of taste.
2. Application of ammonia with the chlorine at three wells so as to permit a higher and more permanent residual.
3. Reduction or cessation of pumping from certain wells.
4. Chlorination of the mains followed by intensive flushing. This work was carried out between 1 A.M. and 6 A.M. every night for several months.

AERATOR AND PUMP STATION
NEW YORK WATER SERVICE CORP., MASSAPEQUA

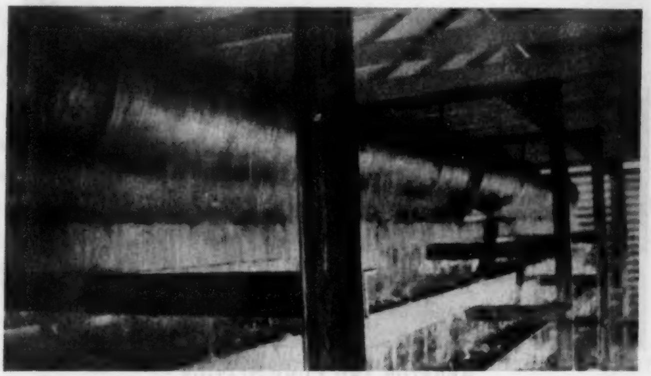
These measures proved satisfactory for the control, but not for the complete elimination of the offending organisms. Occasional mild recurrences of the trouble are not unusual, particularly in the spring.

IRON REMOVAL

There are several iron removal plants in the area previously described as yielding water of high iron content. The method in most general use is aeration, sometimes followed by chlorination and rapid sand filtration. Typical plants of this type will be found at Jamaica, Jameco, Springfield, Rockaway Park, and Valley Stream. Iron removal efficiency is high.

Mention should also be made of two iron removal plants of unique

design. At Flushing the City of New York operates a plant in which iron is removed by lime treatment and pressure filters without the use of air. This plant, which has been completely described by Hale (21), depends on the rapid precipitation of iron as ferrous hydroxide and the subsequent removal of the precipitate by filtration. At Station No. 18 the Jamaica Water Supply Company has recently completed a 2 m.g.d. iron removal plant of the Reisert type. Here the well water is first aerated under pressure by a counter current of compressed air, after which it is filtered through a bed of mixed sand and crushed limestone. The raw water contains an average of about 2.0 p.p.m. iron and very close to 100 per cent removal is secured. At the same time the pH is raised appreciably. It is understood that a similar plant of smaller capacity is under construction at Long Beach.



AERATOR AT MASSAPEQUA

CORROSION CONTROL

Generally speaking, all of the soft Long Island waters are corrosive to metals and preventive treatment is practiced at many plants. This treatment is often a simple application of lime or soda ash, although not a few plants use preliminary aeration followed by alkali treatment. Lime alone is used at Babylon, Bay Shore and Westhampton. Aeration, with or without subsequent alkali treatment, is used at Rockville Centre, Freeport, Massapequa, and Hempstead. These are typical examples and no attempt has been made to catalog all plants using such treatment.

An examination of the "Report of Committee on Pipe Line Friction Coefficients" (18) discloses that the loss of carrying capacity of

water mains on Long Island, due to tuberculation, is great. In general, water with a pH of 6.0 may show a 30 year loss of carrying capacity as great as 80 per cent for some pipe sizes. Few plant operators realize the extent of the losses which they have suffered due to corrosion. This loss may be calculated much more readily in terms of depreciated carrying capacity than in terms of the destruction of iron, because most cast iron pipe is sufficiently thick to withstand severe corrosion for many years without failure, but loss of capacity is continuous and cumulative.

AEROMIX AND RIFFLES
LONG ISLAND WATER CO., VALLEY STREAM

The preservation of carrying capacity in unlined pipe is a problem involving not only the chemical treatment of the water, but also the repeated determination of flow coefficients on the mains. Much work has been done; but, unfortunately, there is little definite evidence, based on carrying capacity, to prove the effectiveness of alkali treatment. The evidence at Pocantico, N. Y., is that alkali treatment retards the rate of corrosion but does not prevent it entirely.

SANITATION

Sanitary supervision of the supplies of the City of New York is vested in the Laboratory Division of the Department of Water Supply, Gas and Electricity, of which Dr. F. E. Hale is Director. New York Water Service Corporation maintains a laboratory and inspection service under direction of the writer. A similar type of laboratory service is operated by the Jamaica Water Supply Company. The County Boards of Health and the State Board of Health exercise an active supervision of sanitation and quality.

Outside the City of New York most of the larger water supplies have rules and regulations which have been enacted by the State Department of Health for their sanitary protection. These rules establish limiting distances for the various types of sources of pollution. A common limiting distance for minor sources of pollution is 200 ft., measured horizontally from the well head. From a sanitary standpoint the most important precautions to be observed in the case of the Long Island wells are: proper construction of the well; a properly designed well head; and the control of a protecting area of land.

Public sewerage systems and disposal plants are relatively few in Nassau and Suffolk Counties. With the exception of a few communities, each house is provided with individual sewerage facilities. This system presents a constant hazard to the safety of small private wells, of which there are a host. Under these conditions the advantages of a well located and properly supervised public water supply cannot be overemphasized.

CONCLUSION

In the foregoing paragraphs an attempt has been made to describe rather briefly the quality of the public water supplies of Long Island and the more common problems encountered in their treatment and sanitation. Many supplies have been omitted because of lack of information and no mention has been made of the numerous individual and industrial water supplies. The water resources of Long Island are unique in their accessibility and naturally excellent quality. The utilization of these waters to the best advantage of all the people represents a large and complicated problem in conservation.
Acknowledgment is made to Mr. N. S. Chamberlin, former Chemist of the New York Water Service Corporation, who performed many of the analyses included herein; to Dr. Frank E. Hale of the Depart-

ment of Water Supply, Gas and Electricity; and to others who have kindly contributed much of the analytical data.

Discussion by R. E. Cook.* Mr. Norcom's paper presents an excellent picture of the water supply situation on the whole of Long Island. While my experience has been largely confined to Suffolk County, yet it has been shown, particularly in the last few years, that the water supply of the Island is one continuous whole and that conditions in Brooklyn continue to affect Suffolk County. To this end the Board of Supervisors of Suffolk County has recently established the Suffolk County Water Authority which has power to prevent diversion of the underground water supply of Suffolk County without proper compensation. In other words, any community or private corporation intending to use more than 100,000 gallons a day or having a capacity to pump such an amount must obtain approval not only from the State Water Power and Control Commission but also from the Suffolk County Water Authority.

The establishment of this Authority was largely due to the fact that the elevation of the underground water supply in Brooklyn has been lowered to at least twenty-five feet below sea level. This lowering is due to excessive pumping, mostly by corporations which desire cooling water and do not use it for domestic purposes. This large draft has resulted in inflow of water from the ocean and East River and also from the neighboring counties of Queens and Nassau and at present from Suffolk County. Under a general State Law the Suffolk County Water Authority was established to guard the underground supply in Suffolk County and to prevent, if possible, or use all legal means to prevent any further depletion or diversion.

The underground water supplies of Suffolk County are largely of excellent quality, both physically, chemically, and bacteriologically, with the following exceptions which Mr. Norcom has expressed in detail:

(1) The corrosion problem, due to the presence of free carbon dioxide in the water.

(2) The presence of iron in some of the water.

(3) The danger of salt water contamination, particularly at the western and eastern ends of Long Island.

(4) The danger in some sections of the location of cesspools and other sources of pollution at too close distance to wells. This is due

* Sanitary Engineer, Suffolk County Health Department, Riverhead, N. Y.

to the fact that the population is rapidly increasing and constant supervision must be maintained of the conditions surrounding the wells in order to prevent the location of any cesspools or source of pollution near the well fields. The lack of public sewer systems makes this supervision necessary for practically all the public supplies in Suffolk County.

I will briefly outline the improvements made during the last eight years relative to the above unsatisfactory conditions.

The corrosion problem is prevalent in practically all the public supplies as well as many of the private supplies. The pH of the public supplies varies largely from 5.5 to 7. With the exception of some of the supplies owned by the Federal Water Service Corporation and the Riverhead Municipal Water District, no attempt is made to treat the water to prevent corrosion. As mentioned by Mr. Norcom, several supplies of the Federal Water Service Corporation have, and are being so treated with lime or soda-ash to neutralize the acidity and carbon dioxide. The rusty water problem, particularly in hot water systems, is quite prevalent. Copper tubing and tanks have been found superior to galvanized ones providing that such pipes and tanks are of high copper content and connections from the cast iron main to the last faucet are of no other metal. Analyses have shown that the public supplies, other than those owned by the Federal Water Service Corporation, are of a higher pH and, therefore, are less corrosive, but, however, the supplies when treated show much better results.

(2) The Patchogue supply of the Federal Water Service Corporation was the only supply with a relatively large amount of iron of the supplies in Suffolk County, and recently this supply has been practically eliminated due to the installation of the Bayport supply which contains practically no iron. The Patchogue supply was also very corrosive, contained a large amount of organic matter and was in close proximity to many cesspools. Its elimination was a great step in improvement of the public water supplies in Suffolk County. The Amityville Supply has been largely eliminated due to the fact that the village is supplied also from the Massapequa source of the Federal Water Service Corporation, which has better chemical quality. As noted by Mr. Norcom, the Sag Harbor supply is a surface one and as shown also by him, a test well at that point shows that the surface ground water contains large amounts of iron, while in the lower strata the water was salt. At the present time the start of construction

has been made on a filtration plant. This water, containing iron, will be pumped from the wells, aerated, treated with lime (possibly), and then filtered. This will eliminate the worst condition of all the public water supplies in Suffolk County as the ponds, which have hithertofore supplied the community, contained large amounts of organic matter and algae, have been high in color and disagreeable in taste, particularly in the warm months. In other words it was a very objectionable supply.

I have noted the salt water conditions at the western end of Long Island but also wish to point out the conditions at the eastern end and also on Fire Island Beach, which lies between the Atlantic Ocean and the Great South Bay. Particular attention must be paid to the village of Greenport which has a municipal supply. This village is located very near the eastern end of the northern fork of the Island and is almost surrounded by salt water. While attempts have been previously made to derive fresh water from deep strata, yet it is felt that very little could be obtained from any deep strata and any large amount of pumping would immediately bring in the salt water with the consequent ruination of the well. This has been confirmed by a recent test well put down at Orient Beach State Park which is still further east of Greenport on the northern fork of the island. This well was put down by the Long Island State Park Commission and showed salt all the way down to four or five hundred feet. It was, therefore, necessary that the water supply for this park be obtained from a point two miles distance from the park on slightly elevated ground and from shallow wells. This further confirmed the experience of the writer, because in 1930 the village of Greenport, the shallow wells of which had become salt or had a large quantity of iron, did the same thing and put down six wells at a depth of fifty-five feet and at a distance from each other of over a hundred feet. These wells were six inch drilled wells and the quantities pumped from each are less than hundred gallons a minute and the total amount pumped from this well field is not over two-hundred thousand gallons a day. These wells have been used now at least six years and the chloride content which was 19.0 at the beginning is now 48.0. But the indications are that it will not grow much higher due to the fact that in the period mentioned a drought occurred. Since the time of the last analysis considerable rain has fallen with the consequent reduction of the salt content.

In the Hampton Bays Water District the sources of water are wells which have salt water on three sides, though at points about a mile from the wells. Because of heavy pumping from one of the wells the chloride content increased from about 10.0 p.p.m. to 60 p.p.m. In the well which pumped only 150 gallons per minute the chloride content was about 14 so it was recommended that the large pump, which had a capacity of 275 gallons per minute be throttled down to not over 175 gallons. This was done and the chloride content was reduced to about 39 and it is to be hoped that with each well pumping not over 175 gallons per minute the chloride content will be kept down so that no irreparable damage will be done.

As mentioned above, the water supplies on Fire Island Beach, which is a narrow strip of land varying from one-third to three-quarters of a mile in width adjoining the Atlantic Ocean on the south side, have always presented a problem. Eight years ago the village of Saltaire had a flowing well about four-hundred feet deep which was free from salt and contamination and of generally satisfactory quality. Ocean Beach and Point O'Woods, however, had a large number of small shallow wells which were not only high in chloride but also somewhat contaminated from a bacteriological standpoint three or four years ago. Only last year both of these communities installed wells of approximately four hundred feet in depth and obtained satisfactory results both from a physical and bacteriological standpoint. The water from the strata of four-hundred feet depth at this point apparently came from rain water which fell on the middle part of Long Island, seeped down beneath clay beds and under Great South Bay to the point from which it is tapped.

Many instances during the last eight years have occurred which have helped to prevent any possible pollution in the public supplies in Suffolk County. It was noted above that the Patchogue supply which has been chlorinated, but nevertheless subject to some contamination has been eliminated. The Amityville source is also on a small area and careful supervision over the area has been maintained but this source has largely been supplanted by the source at Massapequa, the sanitary conditions of which are very much protected. The Ocean Beach and Point O'Woods cases have been mentioned above. The construction of a sewer system at Riverhead with the consequent installation of cast iron pipe within the vicinity of the water works will help to prevent any pollution there. The new sources of supply developed at Bayport, Brentwood and Bridgehampton have all

been located with special view toward the prevention of any possible or potential pollution from cesspools or other human sources. In only four of the thirty-four sources of public supply has it been necessary to chlorinate and two of these, Sag Harbor and Patchogue, have been or are being eliminated. The other two supplies that are chlorinated are Bay Shore and Huntington. The raw waters at both these places have shown satisfactory bacteriological results. Chlorination is used as a precautionary measure because of the fact that Bay Shore supply is located near many houses and at Huntington the tile sanitary sewer passes in close proximity to the plant. All supplies are examined in the laboratory of the Department every month. These results, during the last seven years, have constantly shown the practical absence of organisms of the coliform group in all dilutions tested, with the possible rare exception of one or two 10 cc. dilutions at times.

CONSOLIDATED LIST OF REFERENCES

LONG ISLAND GROUND WATER

(1) Water Committee of the City of Brooklyn, Report. March 13, 1854.

(2) KIRKWOOD, JAMES P. Report Descriptive of the Construction of the Brooklyn Water Works. 1867.

(3) DE VARONA, I. M. Report on History and Description of the Water Supply of the City of Brooklyn. 1896.

(4) FREEMAN, JOHN R. Report Upon New York's Water Supply. March 23, 1900.

(5) BURR, W. H., HERING, R., FREEMAN, J. R. Report of the Commission on Additional Water Supply for the City of New York. November 30, 1903.

(6) VEATCH, A. C., AND OTHERS. Underground Water Resources of Long Island, N. Y. U. S. Geol. Surv. Professional Paper 44. 1906.

(7) VEATCH, A. C. Fluctuations of the Water Level in Wells, with Special Reference to Long Island, N. Y. U. S. Geol. Surv. Water Supply Paper 155. 1906.

(8) FARMER, ALEXANDER S. Geology of Long Island and its Practical Relation to Underground Water Supplies. J. Municipal Engineers of City of New York. March 1907.

(9) SPEAR, WALTER E. Long Island Sources, an Additional Supply of Water for the City of New York. N. Y. Board of Water Supply. 1908.

(10) SPEAR, WALTER E. Brooklyn's Water Supply. J. Brooklyn Engineers' Club. 1909.

(11) CROSBY, W. O. Report on the Geologic Relation of the Ground Water of Long Island, N. Y. Board of Water Supply. 1910.

(12) SPEAR, WALTER E. Long Island Sources. N. Y. Board of Water Supply. 1912.

(13) FULLER, MYRON L. Geology and Underground Water Resources of Long Island, N. Y. U. S. Geol. Surv. Professional Paper 82. 1914.

(14) BRUSH, W. W. Effect of Water Waste Prevention Work on Extension and Operation of the Brooklyn Water Supply System. J. Brooklyn Engineers' Club. 1914.

(15) LAASE, W. F. The Brooklyn Water Supply. J.N.E.W.W.A. **29**: 546 (1915).

(16) LAASE, W. F. Construction and Maintenance of Deep Wells in Sand Strata on Long Island, N. Y. J.A.W.W.A. **24**: 1523 (1932).

(17) LAASE, W. F. Sub-Surface Water Supply of Western Long Island and its Utilization. J. Municipal Engineers. City of New York, Paper 172. 1934.

(18) Committee on Pipe Line Friction Coefficients, Report. J.N.E.W.W.A. **49**: 235 (1935).

(19) LEGGETTE, R. M. Long-time Records of Ground Water Levels on Long Island, N. Y. Trans. American Geophysical Union. Part II. 1936.

(20) THOMPSON, D. G. AND LEGGETTE, R. M. Withdrawal of Ground Water on Long Island, N. Y. N. Y. State Water Power and Control Commission. Bulletin G. W.-1. 1936.

(21) HALE, FRANK E. Iron Removal without Aeration. The Precipitation, of Ferrous Carbonate in a Closed System. J.A.W.W.A. 28: 1577 (1936).

(22) GOODMAN, JOSEPH. The Development of the Water Supply of the City of New York. Water Works Eng. 89: 1382 (1936).

(23) SUTER, RUSSELL. Engineering Report on the Water Supplies of Long Island, N. Y. N. Y. State Water Power and Control Comm. Bulletin G. W.-2. 1937.

(24) THOMPSON, D. G., WELLS, F. G. AND BLANK, H. R. Recent Geologic Studies on Long Island with Respect to Ground Water Supplies. Economic Geology. Vol. 32. 1937.

(25) LEGGETTE, R. M. The Mutual Interference of Artesian Wells on Long Island, N. Y. Trans. American Geophysical Union. 1937.

(26) Records of Wells in Kings County. N. Y. State Water Power and Control Comm. Bulletin G. W.-3. 1937.

(27) Records of Wells in Suffolk County, N. Y. N. Y. State Water Power and Control Comm. Bulletin G. W.-4. 1937.

(28) Records of Wells in Nassau County, N. Y. N. Y. State Water Power and Control Comm. Bulletin G. W.-5. 1938.

(29) Records of Wells in Queens County, N. Y. N. Y. State Water Power and Control Comm. Bulletin G. W.-6. 1938.

(30) SANFORD, J. HOMER. Report on the Geology and Hydrology of Kings and Queens Counties, Long Island. N. Y. State Water Power and Control Comm. Bulletin G. W.-7. 1938.

NOTE—The literature on Long Island ground water supplies is extensive. The references above, if consulted, will indicate the availability of much other published data.

EXPERIENCE WITH GROUND WATER REPLENISHMENT

By Fred H. Tibbetts

Being familiar with but one ground water replenishment project of importance which has been fully completed and has functioned long enough to give reliable information on what may be expected, I shall devote most of this paper to a description of the construction and operation of the Santa Clara Valley Water Conservation District, generalizing briefly toward the close.

This project has a completely independent drainage unit of about 130,000 acres of highly developed fruit and vegetable land, irrigated entirely from wells, with an urban population of about 100,000 in about half a dozen municipalities. Preliminary investigations and the collection of scientific data extended over a period of about twelve years and cost about $40,000. The project has been in operation three years, during which the effect has been accurately observed, and the results are most satisfactory.

Santa Clara Valley is a southward extension of San Francisco Bay and at least the lower end has probably been repeatedly alternately above and below sea-level. The level floor of the valley, which is composed of silt, sand, clay, gravel, etc., has been washed down from the Franciscan shales and sandstones which surround it on three sides. The Franciscan formations are of great age and much broken and shattered by repeated faulting and by serpentine intrusions. Two of the major breaks in the California surface-topography, the San Andreas and the Hayward faults, movements along which have caused severe earthquakes during recent times, pass close to the western and eastern edges of the valley, the surface of which has recently sunk as much as five feet and is still sinking.

Much the largest of the valley's tributary streams, the Coyote River, has worked down into the Hayward Fault. The flood-flow from this stream must be conserved if agriculture is to be preserved

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A paper presented before the California section meeting at Sacramento (October, 1937) by Fred H. Tibbetts, Chief Engineer of the Santa Clara Conservation District.

in Santa Clara Valley. Hence it was found necessary to build the largest of the dams, straddling the Hayward Fault, on what is upon probably as poor a foundation as a large dam ever was built.

The fill comprising the valley floor, probably to a depth of several hundred feet, is a mixture of materials washed down from the surrounding mountains and is heavily interlaced with water-bearing gravel-strata of varying thickness. A study of some hundreds of well-logs spaced as uniformly as possible over the valley indicates that about ten per cent by volume of the total valley-fill is composed of water-bearing gravel or sand. These water-bearing materials or aquifers seem to be buried stream-channels of much the same character as the gravel or sand layers a few feet in thickness found at the bottom of the present active streams. They radiate out from large deposits of gravel and boulders which constitute the alluvial cones of the present streams. Radiating out in such a manner, they follow roughly the general direction of the present surface-drainage, interlace and overlap to a very large extent. The aquifer material, just like that found in the beds of the present streams, is quite open and porous.

As the streams have repeatedly abandoned their channels during the gradual upbuilding of the valley, these very porous gravel and sand-aquifers eventually become buried in silt and clay which, although not watertight, is nevertheless more impervious than the aquifers themselves.

Engineering reports in the past have estimated the volume of this aquifer material from available well-logs, and in so doing have probably overestimated the same. Wells which penetrate one or more of these aquifers are, of course, "good" wells and, as the valley develops, the neighbors tend to bore new wells in the same vicinity in which "good" wells are known to exist. Wells which strike no aquifer material are "dry" wells and tend to be abandoned or forgotten, and the neighbors in boring new wells tend to stay away from the vicinity of such "dry" wells.

In the very extensive investigation of the Mokelumne River flood-plain made by the East Bay Municipal Utility District, this tendency for the wells to group along the line, and in the vicinity of ancient buried channels, was quite marked.

In a valley of this type, serious errors may be involved in the method most common in the past of estimating the change of ground-water storage during a season, or from one season to another, from

well-measurements. A large portion of the total volume between the ground-water levels at the beginning and end of a season and between wells may have changed its total storage-water content but little. The seasonal fluctuation of the water plane level in the wells, especially the drop toward the end of the season, may effect principally the relatively small area of the wells' cone of depression.

About the lower 40 per cent of the valley, including generally the area northward from San Jose, seems to have repeatedly alternated from above to below sea-level. There is a thick blanket of impervious clay, and the aquifers, which are ancient river-channels, seem generally to have pinched out at their lower ends in this impervious clay. These aquifers, being buried in material less pervious than themselves and heading up into the gravel-cones into which water is poured as the mountain surface-drainage debouches onto the valley floor, tend to develop pressure under the marine clays where the area is artesian and, before the period of general overdraft, the pressure was great enough so that the water in wells rose above the natural surface of the ground.

Into this area, formerly artesian, whose upper limits are rather closely determined, water-pressure is quickly transmitted through the aquifers. This area is therefore subject to much more rapid and greater fluctuations in well-measurements at least, if not in the general water-plane, than the areas higher up. This fact has probably led in the past to overestimates of the overdraft. A very considerable portion of the recorded well-fluctuations represent merely variations in pressure rather than variations in volume of water stored underground.

If, as believed, the aquifers pinch out in the marine clays at the lower end of the valley, then the underground storage-basin is enclosed on three sides by the surrounding mountains. Escape of water to the northward is prevented as the aquifers or water-bearing material pinch out into the impervious clays below the level of the Bay. From this underground storage-basin there is, therefore, little marginal or terminal loss.

The formation of underground storage as described for Santa Clara Valley is typical of many other coast and interior valleys of relatively small area, though the artesian condition due to capping the water-bearing material with tight marine clays is an especially favorable condition for preventing terminal losses from underground storage at the lower end of Santa Clara Valley. The underground

basin is completely enclosed and the underground storage consists of the void spaces between the gravel stones, or grains of sand forming the water-bearing material, all more or less connected, and in the aggregate forming a very large total volume.

If ten per cent of the valley fill is water-bearing material and thirty per cent of the water-bearing material is composed of voids for water storage, then three per cent of the total volume of the valley fill can be utilized as an underground storage basin. In the feasible pumping lift of 200 feet, there would be available underground storage under the surface of the 130,000 acre valley of nearly 800,000 acre feet, about eight times the total of the surface storage available.

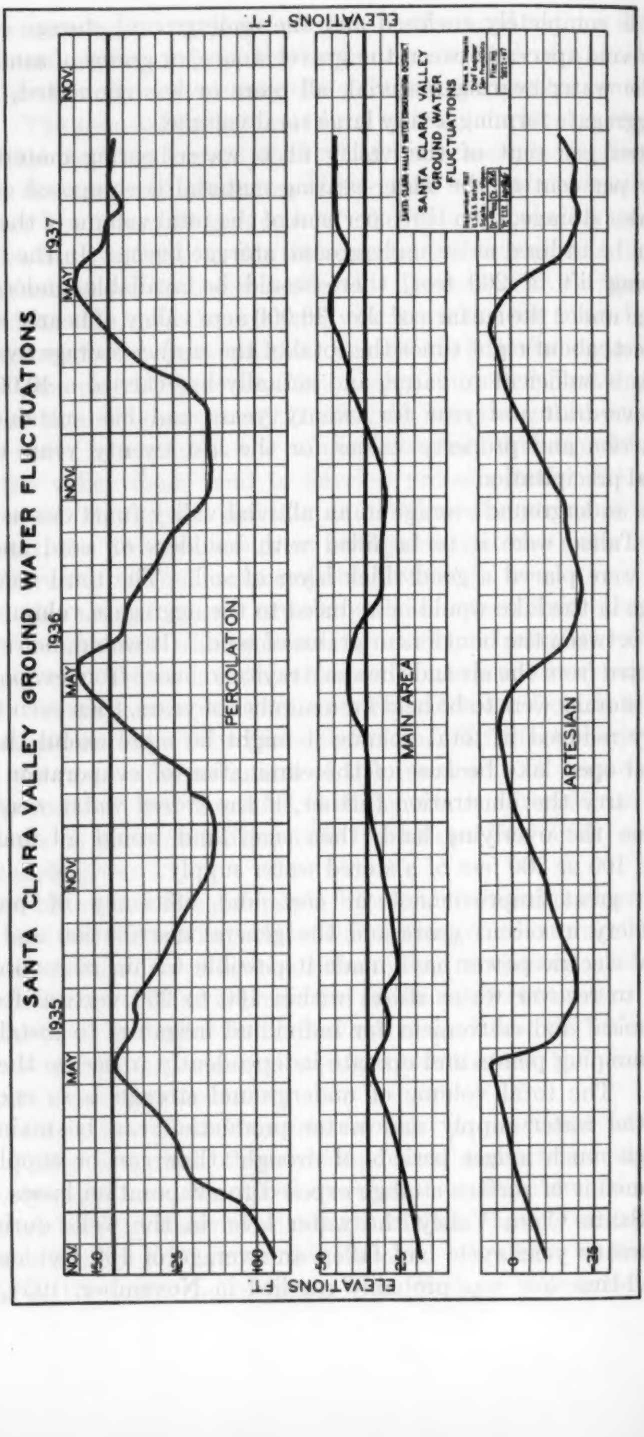
This is sufficient to carry, and actually has carried a 40,000 acre foot overdraft per year for twenty years and has sustained full production and property values for the last twenty years of subnormal precipitation.

The underground storage in an alluvial valley functions as would Lake Tahoe were it to be filled with boulders or sand and over these were placed a good thick layer of soil. The total volume of storage in the lake would be reduced to the aggregate volume of the voids between the boulders or grains of sand. It would, however, be protected from the air and the sun's rays and hence from evaporation. If the storage were to be held for a number of years, then even though greatly reduced in total volume it might be more useful than the natural open lake because of the elimination of evaporation losses.

To carry the illustration further, if the stored water were to be used on the overlying land, then such land would all find itself within 100 or 200 feet of a stored water supply.

The great improvement in cost and efficiency of pumping machinery in recent years and the general distribution and cheap cost of electric power have made it possible within reasonable cost limits to recover water stores within 100 to 200 vertical feet and economical and convenient for individual irrigators to install their own pumping plants and operate independently to secure their own water. The total volume of underground storage is so enormous that the water supply and water production can be maintained through much longer periods of drought than can be supplied by any amount of surface storage exposed to evaporation losses.

In Santa Clara Valley the water level in the wells during the last twenty year cycle had fallen an average of 100 feet or more. The all-time low was probably reached in November, 1934, about


SANTA CLARA VALLEY GROUND WATER FLUCTUATIONS
1935
1936
1937
NOV.
MAY
NOV.
MAY
NOV.
MAY
NOV.
PERCOLATION
MAIN AREA
ARTESIAN
ELEVATIONS FT.
ELEVATIONS FT.
150
125
100
50
25
0
-25
SANTA CLARA VALLEY GROUND WATER FLUCTUATIONS

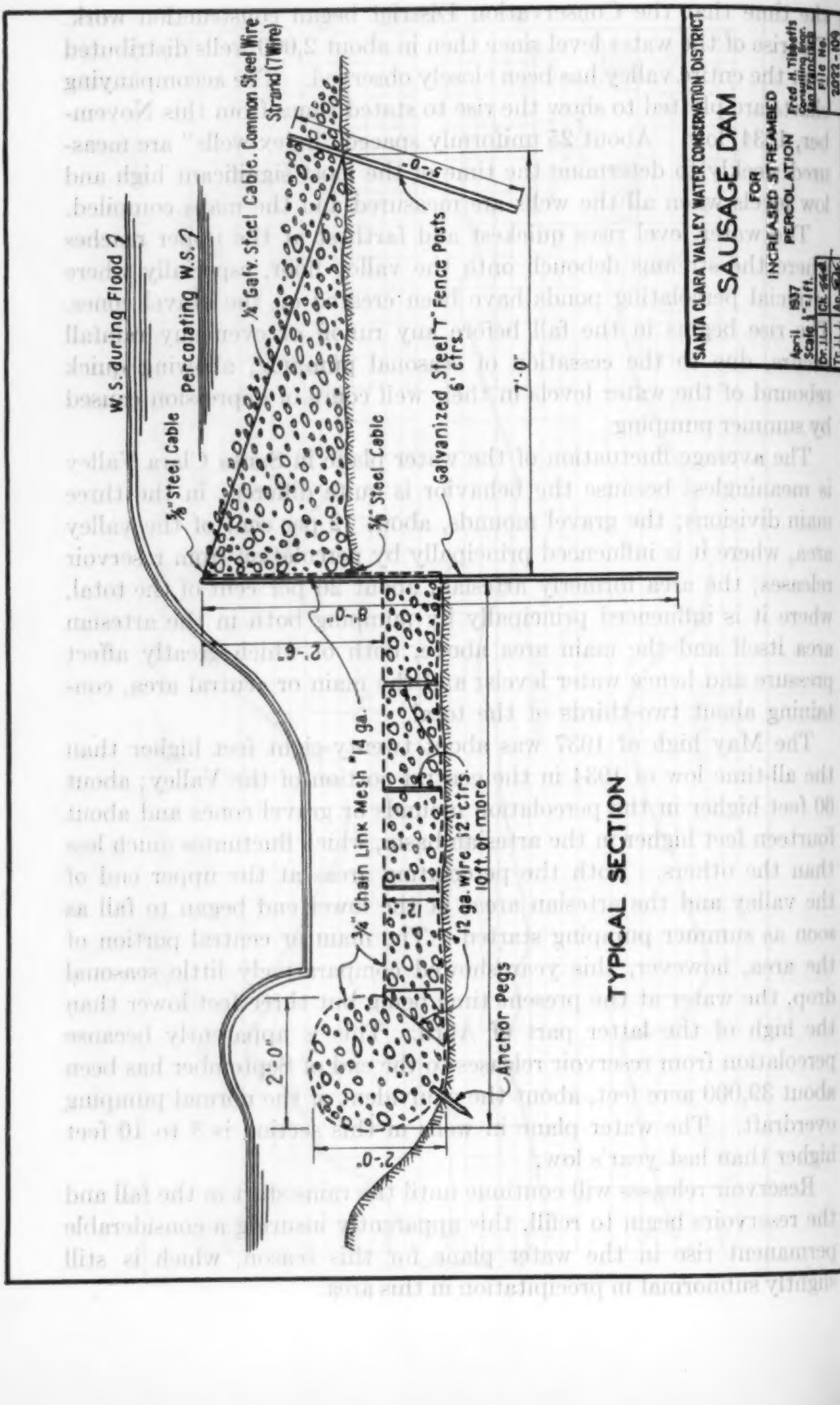
the time that the Conservation District began construction work. The rise of the water level since then in about 2,000 wells distributed over the entire valley has been closely observed. The accompanying charts are plotted to show the rise to stated times from this November, 1934, low. About 25 uniformly spaced "index wells" are measured weekly to determine the time of the most significant high and low levels when all the wells are measured and the maps compiled.

The water level rises quickest and farthest at the upper reaches where the streams debouch onto the valley floor, especially where artificial percolating ponds have been created on the gravel cones. The rise begins in the fall before any runoff or even any rainfall occurs, due to the cessation of seasonal pumping, allowing quick rebound of the water levels in their well cones of depression caused by summer pumping.

The average fluctuation of the water plane in Santa Clara Valley is meaningless because the behavior is quite different in the three main divisions; the gravel mounds, about 12 per cent of the valley area, where it is influenced principally by percolation from reservoir releases; the area formerly artesian, about 26 per cent of the total, where it is influenced principally by pumping both in the artesian area itself and the main area above, both of which greatly affect pressure and hence water levels; and the main or central area, containing about two-thirds of the total.

The May high of 1937 was about twenty-eight feet higher than the all-time low of 1934 in the central portion of the Valley; about 60 feet higher in the percolation mounds or gravel cones and about fourteen feet higher in the artesian basin, which fluctuates much less than the others. Both the percolating areas at the upper end of the valley and the artesian areas at the lower end began to fall as soon as summer pumping started. The main or central portion of the area, however, this year showed comparatively little seasonal drop, the water at the present time being but three feet lower than the high of the latter part of April. This is apparently because percolation from reservoir releases to the end of September has been about 39,000 acre feet, about the equivalent of the normal pumping overdraft. The water plane in wells in this section is 8 to 10 feet higher than last year's low.

Reservoir releases will continue until the rains start in the fall and the reservoirs begin to refill, this apparently insuring a considerable permanent rise in the water plane for this season, which is still slightly subnormal in precipitation in this area.


W.S. during Flood ?
Percolating W.S. ?
3/8" Steel Cable
3/8" Galv. Steel Cable. Common Steel Wire Strand (7 Wire)
3/8" Steel Cable
Galvanized Steel "T" Fence Posts 6' ctrs.
7'-0"
8'-0"
2'-6"
2'-0"
3/4" Chain Link Mesh #4 ga.
12 ga. wire 12" ctrs. 10 ft. or more
Anchor Pegs
TYPICAL SECTION
SANTA CLARA VALLEY WATER CONSERVATION DISTRICT
SAUSAGE DAM
FOR
INCREASED STREAMBED
PERCOLATION
April 1937
Scale 1"=1ft.
Fred H. Tibbetts
Consulting Engr.
San Francisco
File No.
2022-109
PLATE 4

GENERALIZATION

The utilization of underground storage under climatic conditions such as we have requires construction expenditures for:

1. Detention reservoirs near the base of mountainous parts of the water-sheds to detain flood run-off, which usually occurs so rapidly that the bulk of the run-off is wasted, having insufficient time to sink into the ground. The flood waters must be detained long enough so that the reservoir releases will be reduced to the natural or artificially increased capacity of the streams to absorb them and will thus enable all of the detained flood waters to be passed into underground storage.

2. The construction of artificial means of increasing natural stream-bed percolation either in the natural streambed itself or in off-channel absorption areas.

3. Works for the transfer of streamflow and reservoir releases from the streams which have surplus run-off to other streams or other areas deficient in gross water supply.

Detention reservoirs and dams present no problems essentially different from any other class of hydraulic or water supply engineering, and will not be especially described here.

Works for increasing the percolation or absorption capacity of streams consist principally of small stream-bed dams, the purpose of which is with small or medium flows in the river from natural run-off or reservoir releases to increase stream-bed areas which will be covered, the rate of stream-bed absorption being essentially a function of the wetted area. The location of percolating dame to form percolating ponds in the streambeds should be in such locations as stream measurements show absorption rates are highest and where stream-bed topography will enable the maximum area to be covered with water with the minimum length of percolation dams. Stream-bed absorption is generally best on the higher reaches or gravel cones of the streams as they enter the rim of the valleys. Where rates of absorption vary from 1½ feet to as high as 6 or 7 feet per day, wire sausage dams of simple design have been extensively built at a cost of about $7.00 per foot. They should not be more than 2 or 3 feet in height, as if too high they will reduce the bottom velocity of the rivers even in floods so that silting will deteriorate the percolation ponds.

More elaborate, or particularly, higher structures of concrete can be built forming larger ponds only if the super-structures are movable

so that during the flood stages when the water is muddy they will not reduce the bottom velocity. Reservoir releases are of course clarified so that the silting problem is not important.

Gravel areas, especially around the rims of the valleys, can generally be found with a high rate of absorption, and additional water can be sunk into underground storage through such intake areas if diverted from the streams by ordinary diversion dams and canals. There are areas in Santa Clara Valley of this type in which as much as 150 feet in depth of water has been disposed of in a single runoff season of three months.

CONCLUSION

In conclusion, Santa Clara Valley is probably typical of many coast or interior valleys in which a considerable portion of the volume beneath the surface is aquifer or water-bearing material and the total volume of underground storage is large, and being protected from evaporation will sustain production for long periods of drought.

Dependence upon such underground storage will tend toward the utilization of the maximum or average run-off, and this requires detention reservoirs to hold flood flows back until they can be passed into underground storage. Auxilliary construction work designed to increase the rate at which surface run-off can be passed into underground storage is generally required.

The maximum water supply is of course limited by the average precipitation of the watershed, and to develop anywhere near this would ordinarily require extensive surface storage to detain floods long enough to allow them to pass into underground storage. Probably the most difficult general problem is to shift the surface water around so that the surface of the underground storage basin will rise uniformly.

The writer ventures to predict a very great extension in the future of this method of water storage. This may extend over all the western states and perhaps farther into the areas which normally have abundant water but during long periods of drought may require more complete use of available water. Where the soil is sufficiently productive this may eventually offer a solution of the dust-bowl problem of the southwest.

HYDRAULIC CHARACTERISTICS OF VARIOUS CIRCULAR SETTLING TANKS

By George E. Hubbell

SYNOPSIS

Circular tanks have long been used for sedimentation purposes in connection with industrial processes, waste control, water, and sewage treatment. In the design of such tanks, stress has been laid on obtaining the proper detention time for suitable removal of the suspended matter. Little attention has been paid to the hydraulics of the inlet, with a consequent loss in tank efficiency. By means of a model, various inlets were observed and a new type inlet developed appearing to have improved hydraulic characteristics which will increase solid removals now being obtained with accepted types of inlets.

INTRODUCTION

The fundamental process to be employed in the treatment of Detroit's sewage is primary sedimentation. Circular tanks were one of the various types of tanks which appeared suitable for this purpose. Accordingly, plans were prepared for a series of tanks having a diameter of 200 feet, a center depth of 14 feet 9 inches and a side wall depth of 13 feet 9 inches. The proposed plan contemplates eight tanks with center feed, each supplied by an 84-inch circular conduit. The nominal flows and detention periods are given in table 1. While these tanks are not unique in their large size, none such have been used for sewage treatment, the more customary maximum diameter being 106 feet such as those at Washington, D. C. The 90 minute average detention rate and large tank diameter combine to give a tank flow of unusually large proportion; and it was recognized that it would be desirable to model the inlet proposed by the manufacturer to observe the hydraulic performance of the tank. Accordingly, a 1 to 24 scale model was constructed and

A paper presented by Prof. Geo. E. Hubbell of the Department of Civil Engineering, Wayne University, Detroit, Michigan at the meeting of the Central States section held in Dearborn, Michigan, August, 1937.

operated in accordance with Froudes Law. It was not contemplated that the work performed would directly give the relative efficiency of the various types of inlets tested in so far as actual removal of suspended matter is concerned, for it is recognized that the effect of flocculation and the relative effect of velocity would need to be considered.

All of the work was premised on the following theory; i.e., the inlet which would best promote sedimentation would:

1. Cause the tank to detain the initial high thread of velocity the greatest length of time. (This was determined by noting the time that the color took to travel from the center of the inlet to the weir, and obviously represents the maximum velocity at which some particle might travel through the tank.)

2. Cause the average velocity as indicated by floats, to approach the nominal velocity as nearly as possible.

TABLE 1

1950 DESIGN	NOMINAL TIME DETENTION	FLOW TO EACH TANK		VELOCITY IN 84" INLET TUNNEL	NOMINAL VELOCITY IN TANK	TOTAL PLANT FLOW IN
	minutes	*m.g.d.*	*c.f.s.*	*f.p.s.*	*f.p.m.*	*c.f.s.*
Average	90	52.4	81.0	2.11	1.11	648
Maximum	40	121.3	187.5	4.90	2.50	1,500

3. Prevent back eddy currents with attendant inefficient use of portions of the tank due to high velocity.

4. Prevent zones of high velocity that would scour the sludge blanket in the vicinity of the inlet.

5. Cause the tank to detain as nearly as possible all the sewage for the nominal detention time.

It would appear that the foregoing five criteria would indicate to a large degree the relative effect on settling efficiency produced by the various inlets tested regardless of other factors that may be involved.

CIRCULAR TANK DESIGN

One of the inherent difficulties encountered in the design of circular tanks is that, regardless of size, the influent is introduced at the center point. Thus for similar detention periods a 50-foot tank is fed 5 c.f.s.; a 100-foot tank is fed 20.2 c.f.s.; and a 200-foot tank, 81 c.f.s. In terms of energy, sewage is fed into the 200-foot tank

at a velocity of 126.6 feet per minute, and theoretically travels through the tank at a velocity of 1.11 feet per minute. Thus 81 c.f.s. must lose .63 horse power of energy. In the 50-foot tank, 5 c.f.s. must lose .039 horse power of energy. It is the dissipation of this energy that presents the real problem in circular tank design. The theorists' vision of a tank in which there is a uniform deceleration from center to periphery is nonexistent. In the present circular tanks, the energy dissipation apparently takes the form of unequal velocity distribution. It is quite apparent that the inlet problem involved in the design of the 50-foot tank is of lesser magnitude than that of the 200-foot tank. Also, in each of these tanks the sludge is brought back to the same point but in the larger, 16 times as much flow is dispersed where the sludge is being collected.

In any case, there are certain fundamentals that must be adhered to for best performance. Regardless of tank diameter, the following rules should be followed:

1. Creation of uniform velocity distribution in the vertical riser feeding the tank. It is imperative that the energy content of the rising water impinging on the central feed diffuser be maintained at a uniform level. This necessitates nullification of the effects of elbows, or tees, etc., used to turn the flow into the vertical riser. This rule is most often neglected in tank design.

2. Adoption of a diffuser design that will actually take the flow from the vertical riser and diffuse it over an appreciable depth of the tank. This must be accomplished without undue loss of head or the introduction of devices that will clog.

3. The energy given up by the flow must be dissipated without attendant high velocity or turbulent effects in the tank.

4. A zone of low velocity (preferably less than 1 foot per minute, but not greater than 10 feet per minute) should be maintained on the tank bottom adjacent to the sludge blanket.

5. There can be no question of the desirability of protecting tanks from the effects of wind and temperature changes. Such protection generally takes the form of covers and in the larger diameters introduces a problem in structures. With two similar tanks, one covered and one uncovered, the protected tank would give better removals.

TESTS OF STANDARD TYPE INLET

The manufacturers' design for the 200-foot diameter circular tank consisted of the 84 inch inlet tunnel feeding into a 90° elbow of 5-foot radius with a vertical, slightly flaring, riser on which was set a stand-

ard type diffuser having large vertical ports. This is shown in figure 1. The diffuser is surrounded by a 32-foot circular solid baffle extending from above the surface to within 6 feet of the bottom of the tank. This will be recognized as the type of inlet design commonly employed on the majority of circular tanks. With reference to the prototype, the tank will perform in the following manner: With a nominal 90-minute detention and a theoretical velocity of 1.11 feet per minute, some particles would pass through the tank

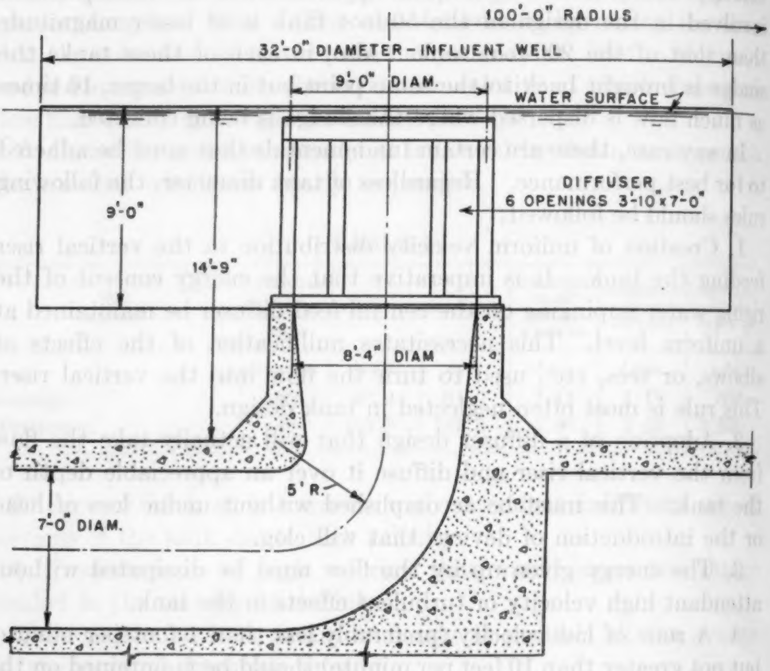


FIG. 1. CONVENTIONAL DESIGN OF INLET FOR CIRCULAR SETTLING TANK

with an average velocity of 9.7 feet per minute and appear at the effluent weir in 11.4 per cent of the nominal time, having been given 10.3 minutes detention. With a nominal 54-minute detention and theoretical velocity of 2.5 feet per minute, some particles would pass through the tank with an average velocity of 14.6 feet per minute and appear at the weir in 12.7 per cent of the nominal time, having been given a detention of 6.85 minutes.

There are several objectionable features to the performance of this inlet.

1. The center casting, commonly called the diffuser, is misnamed since rather than diffusing the flow uniformly through its ports, it projects it at high velocity adjacent to the surface. The flow then impinges on the solid baffle and thence is projected vertically down the face of the baffle, striking the bottom of the tank. It is estimated that at the 54 minute rate the flow would strike the bottom with a velocity of 60 feet per minute. Since it is at this point that all

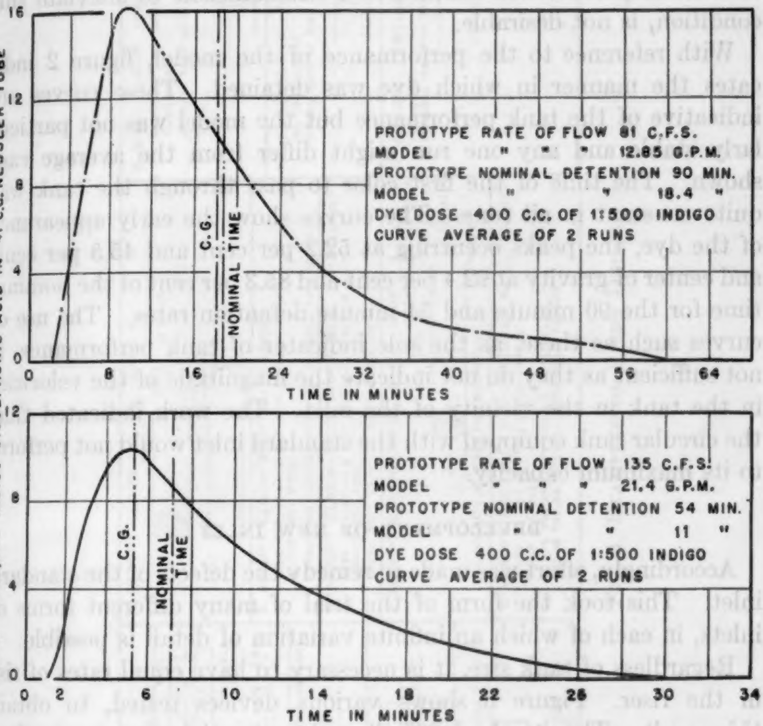


FIG. 2. DYE TESTS OF MODEL TANK EQUIPPED WITH STANDARD INLET

sludge is being returned by the scrapers, it would appear highly undesirable to have a bottom velocity of this magnitude.

2. The central area, comprising 50 per cent of the total tank area is affected by a return roll to the inlet. This roll is caused by the downward flow leaving the 32 foot circular baffle. It is evident that portions of the tank are not being used in an efficient manner and that as long as a roll exists there will always be zones of relative high velocity.

3. The central diffuser casting does not distribute the flow equally to all parts of the tank. Due to the elbow preceding the vertical riser, the velocity distribution in the riser is not normal, consequently the flow has a non-uniform energy content impinging on the diffuser plate, giving unequal diffusion away from the diffuser.

4. The solid baffle extending above the surface forms a trap for floating solids which necessitates their manual removal. The introduction of ports at the surface of a size sufficient to alleviate this condition, is not desirable.

With reference to the performance of the model, figure 2 indicates the manner in which dye was detained. These curves are indicative of the tank performance but the model was not particularly stable and any one run might differ from the average case shown. The time of the first color to pass through the tank was quite constant in all runs. The curves show the early appearance of the dye, the peaks occurring at 52.2 per cent and 45.5 per cent, and center of gravity at 92.4 per cent and 85.3 per cent of the nominal time for the 90 minute and 54 minute detention rates. The use of curves such as these, as the sole indicator of tank performance, is not sufficient as they do not indicate the magnitude of the velocities in the tank in the vicinity of the inlet. The work indicated that the circular tank equipped with the standard inlet would not perform to its maximum capacity.

DEVELOPMENT OF NEW INLET

Accordingly, effort was made to remedy the defects of the standard inlet. This took the form of the trial of many different forms of inlets, in each of which an infinite variation of detail is possible.

Regardless of tank size, it is necessary to have equal rates of rise in the riser. Figure 3 shows various devices tested, to obtain this result. The standard 90° elbow is not satisfactory, as it gives unequal rates of rise and consequent unequal distribution from the diffuser.

Tangential entrance is undersirable, producing a marked spiral flow in the riser, with turbulence at the standard diffuser casting and unequal diffusion. An abrupt tee with water pocket causes eddy currents and marked differences in rate of rise. Abrupt elbows give unequal rates of rise with turbulent conditions in the riser. This turbulence was reduced somewhat by means of vertical vanes in the riser. Abrupt enlargement into a square or circular well with guide

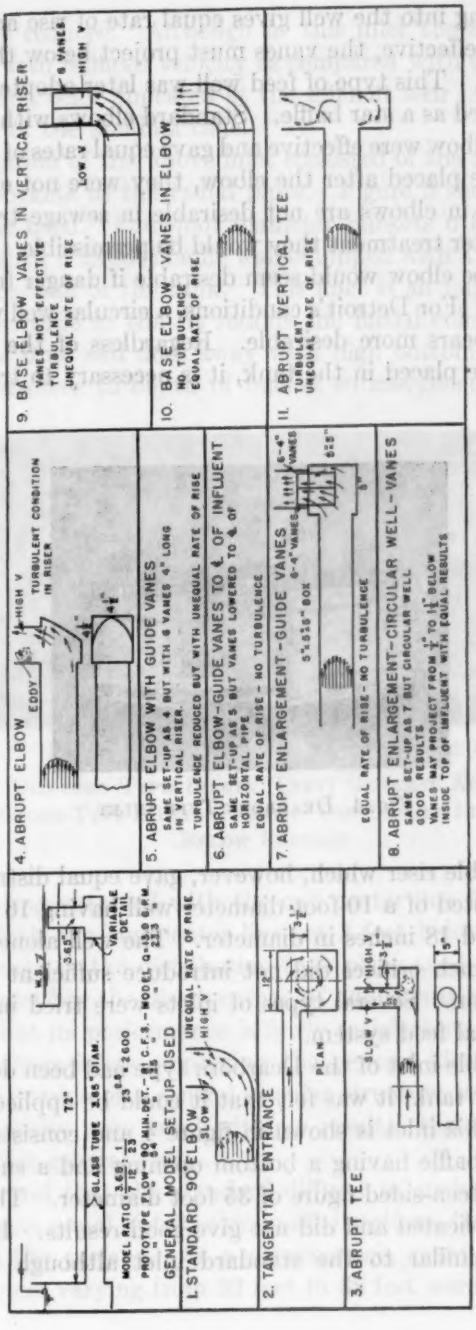


FIG. 3. EXAMPLES OF RISER DETAILS

vanes projecting into the well gives equal rate of rise and no turbulence. To be effective, the vanes must project below the inside top of the influent. This type of feed well was later adopted, the vanes being designated as a star baffle. Standard elbows with guide vanes placed in the elbow were effective and gave equal rates of rise. When the vanes were placed after the elbow, they were not effective. In general, vanes in elbows are not desirable in sewage treatment, although for water treatment they would be permissible. For smaller tanks, this type elbow would seem desirable if danger from clogging is not present. For Detroit's conditions, a circular well with vertical star baffle appears more desirable. Regardless of the type of diffuser and baffle placed in the tank, it is necessary to treat the riser as indicated.

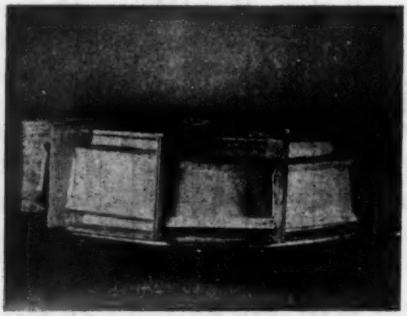


Fig. 4. Dearborn Type Inlet

A less desirable riser which, however, gave equal distribution into the tank consisted of a 10-foot diameter well having 16 radial pipes 11 feet long and 18 inches in diameter. The well alone with a like number of 21-inch orifices did not introduce sufficient loss to give good distribution. Several types of inlets were tried in connection with this central feed system.

Since a suitable inlet of the Dearborn type had been developed for the rectangular tank, it was felt that it could be applied to the circular tank. This inlet is shown in figure 4 and consists essentially of an inclined baffle having a bottom opening and a submerged lip placed on a sixteen-sided figure of 35 foot diameter. This inlet was relatively complicated and did not give good results. It performed in a manner similar to the standard inlet although the bottom

velocity was reduced. Although in this inlet the flow left the lip of the weir with reduced velocity as compared with the 32-foot solid baffle, the first color appeared at the effluent weir in approximately 12 per cent of the nominal time.

An adaptation of the above inlet consisted of the addition of Clifford type buckets to the radial pipes. Figure 5 shows the general arrangement tried. Four-foot diameter buckets 6 feet long return the flow against a 28-foot baffle wall equipped with a 3-foot lip 4 feet above the bottom of the tank. This inlet is an improvement over the standard type in that it retains the initial color 20 percent of the nominal time and does away with high bottom velocity. The inlet was sensitive to depth of bucket submergence; the best performance being obtained with the cup center line 6 feet below the surface. With the cup center line set 3 feet below the surface, a marked change in the distribution took place as shown in figure 6. This type inlet has the disadvantage of added cost and construction difficulties but its performance is fairly satisfactory.

FIG. 5 FIG. 6

FIG. 5. CLIFFORD TYPE INLETS (LEFT) GENERAL ARRANGEMENT
FIG. 6. CLIFFORD TYPE INLETS (RIGHT). CUP CENTER LINE THREE FEET BELOW SURFACE

Various other inlets employing the general idea of distribution around the outside of a central circular structure to obtain reduced entrance velocity were tried without result. Figures 7 and 8 are typical of this general type.

It was found that the standard diffuser in conjunction with the star baffle gave equal distribution in all directions, the flow, however, being near the surface. As a consequence, many circular baffles with diameters varying from 32 feet to 38 feet were tried. Figures

9, 10 and 11 show various baffles observed. Baffles similar to these have been used in many tanks, the thought being that the slots will permit flow to escape through the baffle. This does not occur and the addition of such slots to solid baffles has no beneficial effect. Once the flow is turned downward, it matters little whether the baffle is deep, shallow, or slotted. If the slots continue above the surface and permit some of the flow to escape, though without being deflected down, slightly better operation will result although such a baffle, while reducing bottom velocity, creates many cross currents and permits initial color to reach the weir in 10 per cent of nominal time. In general, baffles of this type are not desirable and cannot be made to retain the initial color more than 10 to 12 per cent of the nominal time.

Fig. 7

Fig. 8

Figs. 7 and 8. Models of Inlet Structures—Circular Type Baffles

In an effort to force the flow to use the entire port area provided by the diffuser, various types of conical diffusers were tried. Figure 12 is typical of this type. Trials of this diffuser verify the fact that the flow follows surfaces and is not easily forced through the ports provided.

It was realized that as long as the diffusers were dispersing the flow adjacent to the surface with high velocity, it would be difficult to introduce baffles surrounding the diffuser that would be effective. Accordingly, a device to pick off the flow at various depths of the diffuser port opening was developed. This development is called a multiple plate diffuser and consists essentially of flat plates set one above the other with concentric holes of decreasing diameter. Each plate forms a surface which flow will follow. Thus an installation of five plates including a solid upper one will reduce the velocity of

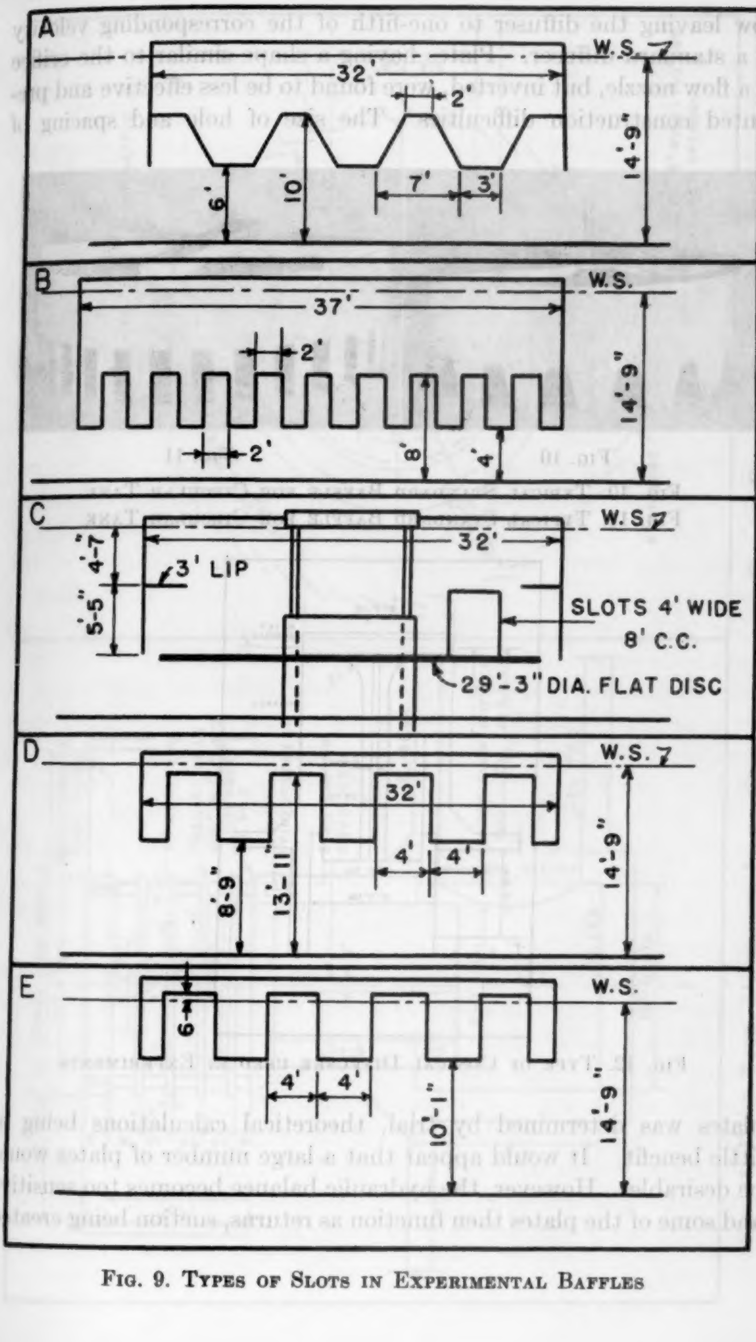


FIG. 9. TYPES OF SLOTS IN EXPERIMENTAL BAFFLES

flow leaving the diffuser to one-fifth of the corresponding velocity of a standard diffuser. Plates having a shape similar to the orifice in a flow nozzle, but inverted, were found to be less effective and presented construction difficulties. The size of hole and spacing of

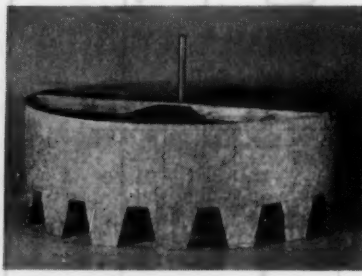


Fig. 10

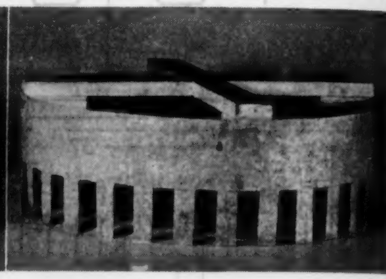


Fig. 11

Fig. 10. Typical Standard Baffle for Circular Tank
Fig. 11. Typical Standard Baffle for Circular Tank

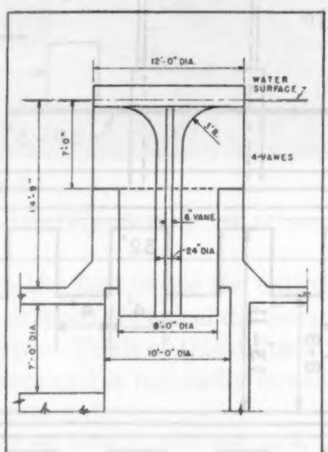


Fig. 12. Type of Conical Diffuser used in Experiments

plates was determined by trial, theoretical calculations being of little benefit. It would appear that a large number of plates would be desirable. However, the hydraulic balance becomes too sensitive and some of the plates then function as returns, suction being created

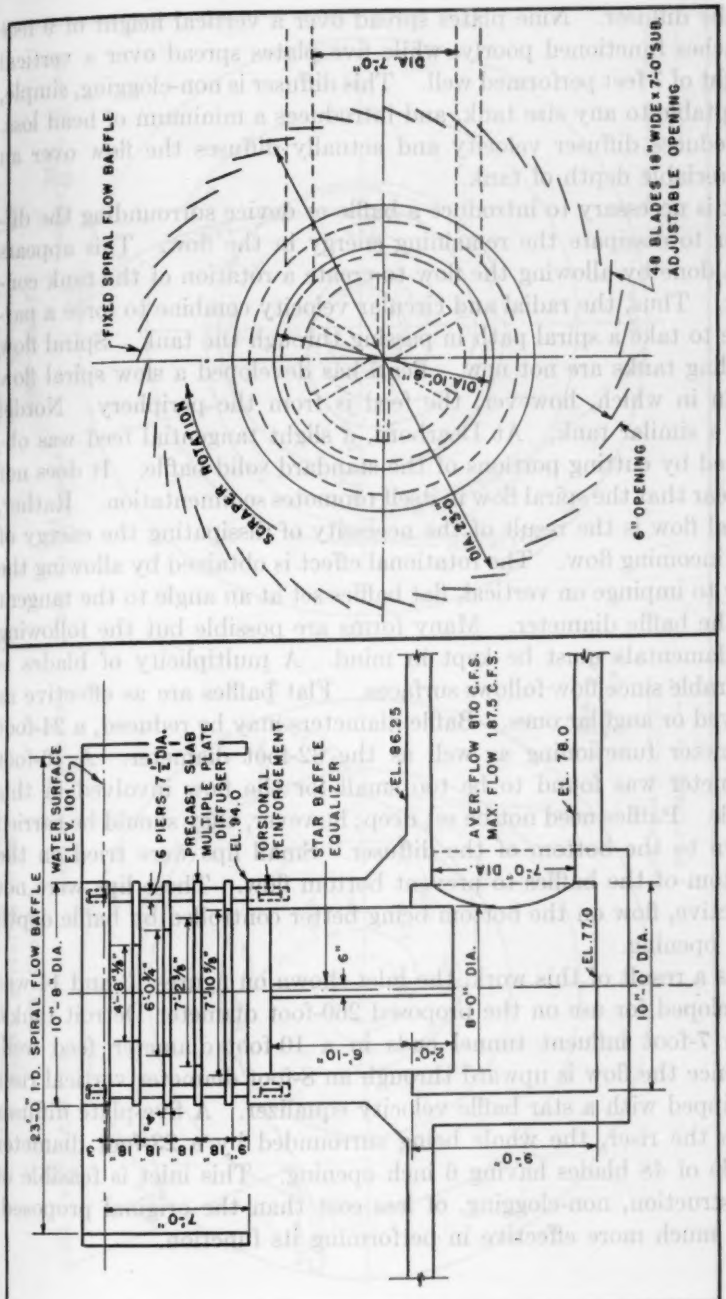


FIG. 13. FINAL TYPE DEVELOPED INLET—SECTION

FIG. 14. FINAL TYPE—DEVELOPED INLET—PLAN

at the diffuser. Nine plates spread over a vertical height of 9 feet 9 inches functioned poorly, while five plates spread over a vertical height of 7 feet performed well. This diffuser is non-clogging, simple, adaptable to any size tank, and introduces a minimum of head loss. It reduces diffuser velocity and actually diffuses the flow over an appreciable depth of tank.

It is necessary to introduce a baffle or device surrounding the diffuser to dissipate the remaining energy in the flow. This appears best done by allowing the flow to create a rotation of the tank content. Thus, the radial and circular velocity combine to force a particle to take a spiral path in passing through the tank. Spiral flow settling tanks are not new. Pearl has developed a slow spiral flow basin in which, however, the feed is from the periphery. Nordel has a similar tank. At Dearborn, a slight tangential feed was obtained by cutting portions of the standard solid baffle. It does not appear that the spiral flow in itself promotes sedimentation. Rather, spiral flow is the result of the necessity of dissipating the energy of the incoming flow. The rotational effect is obtained by allowing the flow to impinge on vertical, flat baffles set at an angle to the tangent to the baffle diameter. Many forms are possible but the following fundamentals must be kept in mind. A multiplicity of blades is desirable since flow follows surfaces. Flat baffles are as effective as curved or angular ones. Baffle diameters may be reduced, a 24-foot diameter functioning as well as the 32-foot diameter. A 16-foot diameter was found to be too small for the flow involved in this work. Baffles need not be set deep; however, they should be carried down to the bottom of the diffuser. Small lips were tried on the bottom of the baffles to prevent bottom flow. These lips were not effective, flow on the bottom being better controlled by baffle depth and opening.

As a result of this work, the inlet shown on figures 13 and 14 was developed for use on the proposed 200-foot diameter Detroit tanks. The 7-foot influent tunnel ends in a 10-foot diameter feed well. Thence the flow is upward through an 8-foot diameter vertical riser equipped with a star baffle velocity equalizer. A five-plate diffuser caps the riser, the whole being surrounded by a 23-foot diameter baffle of 48 blades having 6 inch opening. This inlet is feasible of construction, non-clogging, of less cost than the original proposed, and much more effective in performing its function.

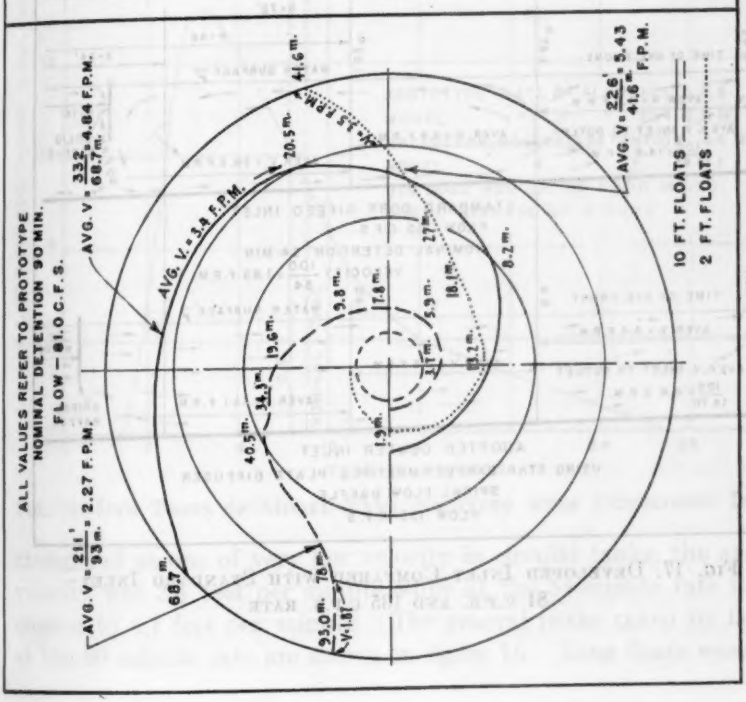


FIG. 15. FLOW CHARACTERISTICS—DEVELOPED INLET—AT 90 MINUTE RATE

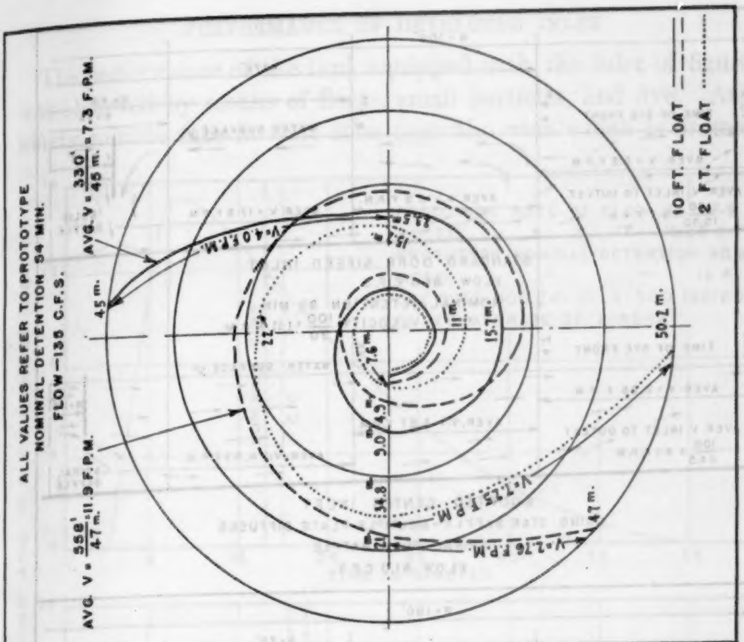


FIG. 16. FLOW CHARACTERISTICS—DEVELOPED INLET—AT 54 MINUTE RATE

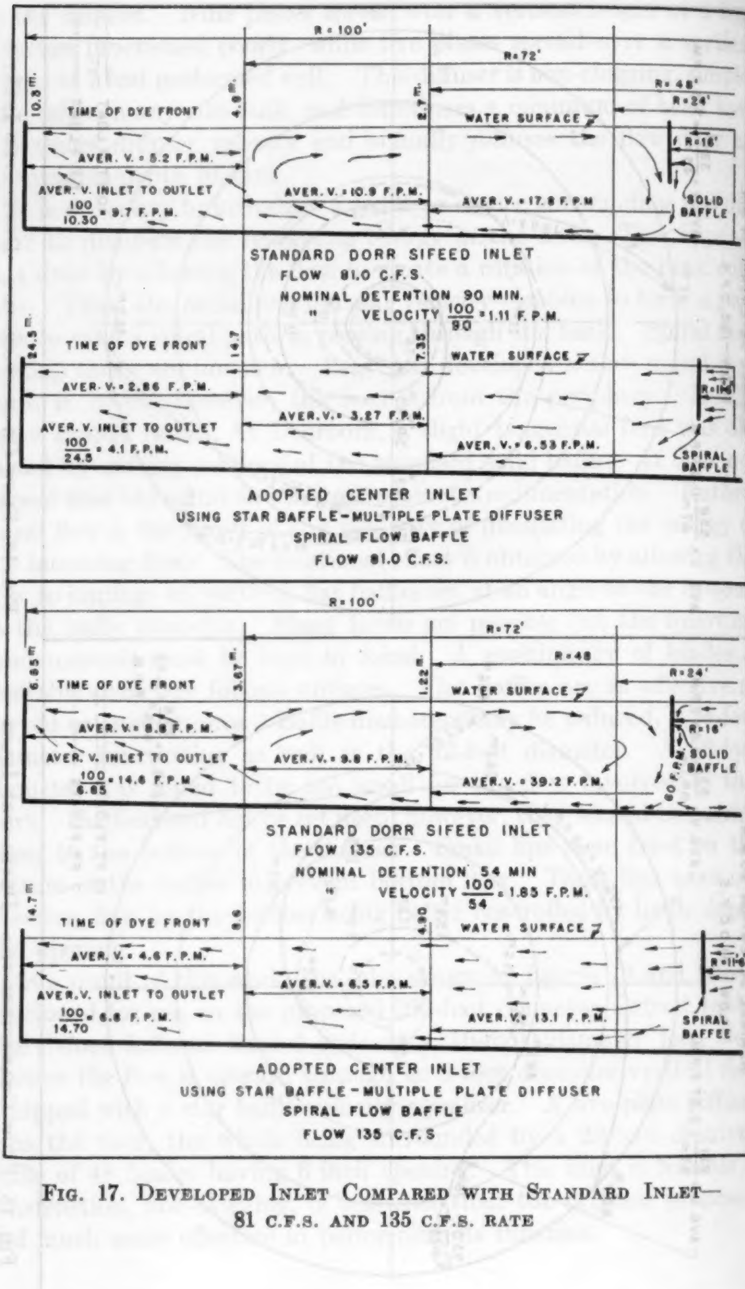


FIG. 17. DEVELOPED INLET COMPARED WITH STANDARD INLET—81 C.F.S. AND 135 C.F.S. RATE

PERFORMANCE OF DEVELOPED INLET

The performance of the tank equipped with the inlet of figure 13 was observed by means of floats, small particles, and dye. At the ninety minute rate in that zone near the weir which is ordinarily

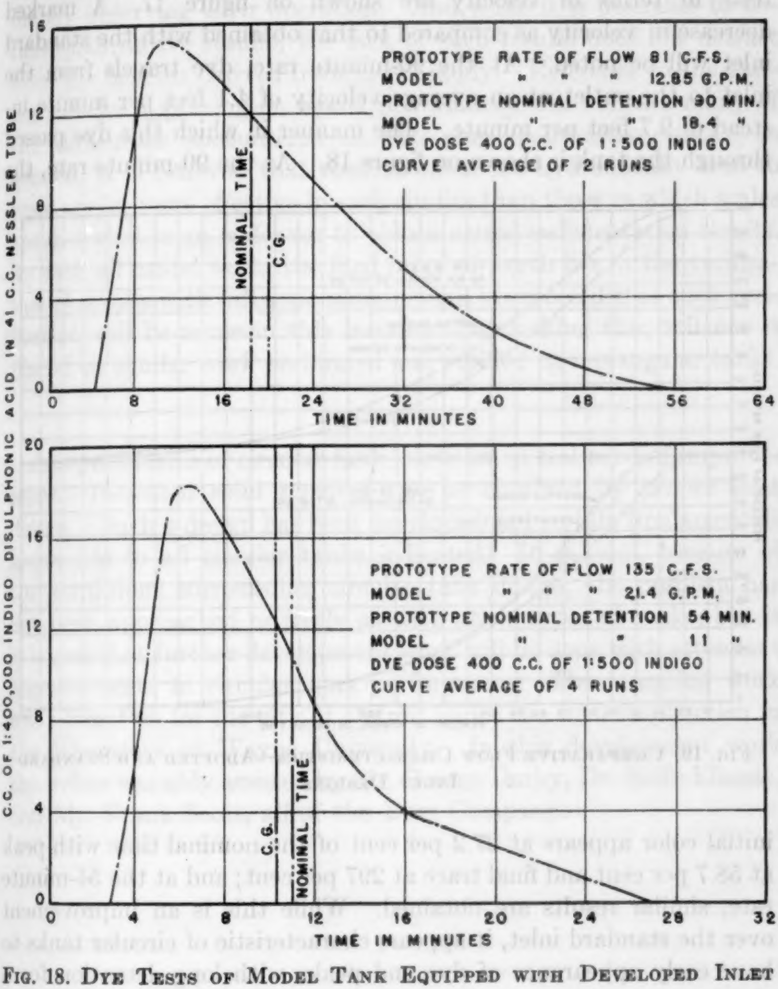


FIG. 18. DYE TESTS OF MODEL TANK EQUIPPED WITH DEVELOPED INLET

thought of as one of very low velocity in circular tanks, the actual velocity was 2.4 feet per minute while at the 54-minute rate it increased to 4.1 feet per minute. The general paths taken by floats at the 90 minute rate are shown on figure 15. Long floats were re-

tained approximately 90 per cent of the nominal time with velocities in the outer 25 feet of the tank ranging from 2.0 to 3.5 feet per minute. Similar data taken at the 54-minute rate are shown on figure 19, the velocities being correspondingly higher. The results of dye tests in terms of velocity are shown on figure 17. A marked decrease in velocity as compared to that obtained with the standard inlet will be noted. At the 90-minute rate, dye travels from the inlet to the outlet at an average velocity of 4.1 feet per minute instead of 9.7 feet per minute. The manner in which this dye passed through the tank is shown on figure 18. At the 90-minute rate, the

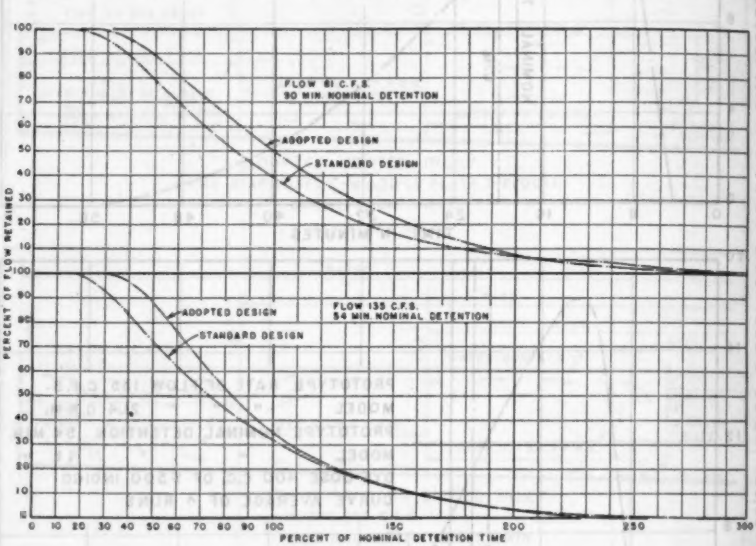


FIG. 19. COMPARATIVE FLOW CHARACTERISTICS—ADOPTED AND STANDARD INLET DESIGNS

initial color appears at 27.2 per cent of the nominal time with peak at 58.7 per cent and final trace at 297 per cent; and at the 54-minute rate, similar results are obtained. While this is an improvement over the standard inlet, it appears characteristic of circular tanks to have early appearance of dye and peaks with long detention for a small portion of the flow. This is best illustrated by means of percentage retention curves. This curve (fig. 19) gives the per cent of the nominal time any percentage of the flow will be detained by the tank and again illustrates the improvement obtained with the new type of inlet.

USE OF MODELS

The use of models for conducting the type of work described herein, permits the trial of many inlet forms with a minimum expenditure of time and money. Much may be done in a qualitative way by merely observing their operation. And while it is desirable to obtain quantitative results, the lack of such results does not detract from the benefits derived from model study. Reference to the various articles appearing on model performance will indicate many of the difficulties encountered in obtaining quantitative data. In general, it is believed that models which are hydraulically true to scale are far more effective in such studies than those in which scales are distorted in an endeavor to obtain actual sedimentation results. As with all model work, the final proof of worth lies in the verification of results with full scale structures, it is expected that such verification will be made in this instance; but lacking this, reliance is placed on similar work performed and verified on rectangular tanks.

CONCLUSION

Accepted forms of circular tank inlets are in real need of improvement. Increased solid removal can be obtained by proper inlet design. Such a design has been developed and certain fundamentals applicable to all circular tanks indicated. In general, because of the conditions surrounding circular tank design, the problem has not been approached as freely as with other types of tanks; but it is hoped that further development work will be done with attendant improvements in circular tank performance. The foregoing work was carried on for the city of Detroit under the writer's direction in the laboratory of Wayne University. In this development work the writer was ably assisted by Mr. George Darby, Dr. Rolfe Eliason, and Mr. Frank Scott, all of the Dorr Company.

ABSTRACTS OF WATER WORKS LITERATURE

Key. **29:** 408 (Mar. '37) indicates volume 29, page 408, issue dated March 1937. If the publication is paged by issues, **29:** 3: 408 (Mar. '37) indicates volume 29, number 3, page 408. Initials following an abstract indicate reproduction, by permission, from periodicals as follows: *B. H.—Bulletin of Hygiene (British); C. A.—Chemical Abstracts; W. P. R.—Water Pollution Research (British).*

WATER SUPPLY—GENERAL

The Provincial Water Supply Company of Groningen, Holland. Water (Neth.) 21: 157 (Aug. 27, '37). I. General Outline. Dr. Ir. G. J. de Glee. As result of a sanitary survey concluded in '10 by Public Health Service, attention was directed to the generally unsatisfactory condition of water supplies throughout the province, with but few exceptions. The provincial government thereupon set to work and elaborated a comprehensive plan for a provincial supply, as in the sister province of North Holland. The two reports embodying this plan, one on the financial set-up, the other on the necessary distribution system, were issued in '13; but, before any action could be taken, the war broke out. Then came the depression, resulting in prolonged inaction. At last in '27 several of the communities, feeling that they could no longer wait upon the province, began to plan independent supplies. The province, realizing that such a move would be fatal to its long-cherished comprehensive scheme, was stirred to action. In '29, the provincial company finally took shape. The province itself and the several communities are the shareholders. Of the 57 communities, Groningen City, which has an excellent water supply, and two others are excluded. Of the remaining 54, 44 have already taken up their shares. The respective allotment to each community has been carefully worked out in advance; when all 54 shall have taken up their shares, the total share capital, reckoning the guilder at 55¢, will be the modest one of $67,000 (*fl.* 122,000), of which the province holds $5,500 (*fl.* 10,000). Each shareholder, moreover, is called on to assume its pro rata share of liability, as to both interest and redemption, for the company's borrowings. It must also guarantee either a certain fixed minimum of water consumption, or, alternatively, compulsory connection of individuals with the supply. Despite considerable opposition, the latter course has been the one uniformly favored. The 5″ (125 mm.) main is regarded as the standard size for a community supply; but only the communities most distant from the source of supply can have mains so small; each community's mains must accommodate not only their own supply, but also that for the communities more distant. As the system is being extended from the pumping station outwards, it follows that the mains first being laid are unnecessarily large for their present duty. To compensate the company to some extent for this added burden, the province has agreed to finance temporarily on an interest-free basis one half of this extra

expense, and has to date advanced \$28,000 of the \$138,000 already expended on the distribution system. The difficulty of determining the most economical plan for the province's supply was considerable. Only at certain locations near the Drenthe border are supplies ample in quantity and satisfactory in quality available. Five different plans were worked out and it became clear that a single pumping station at Onnen was the correct solution. The maximum allowable pressure was fixed at 150 lbs. Two parallel mains (20", already built, and 28") about 3 mi. long will run from Onnen to Hoogezand, there to join. From there radiate the three primary mains, one to the east and southeast, one to the northeast, and one to the northwest, to cover the whole province. There will be seven water towers, all floating on the system; to four of them booster pumps will be attached for the benefit of the more remote districts. Their capacities will vary from 150,000 to 265,000 gal.; the high and low water levels will be the same for all, at elev. 147.6 and 114.8 respectively. Ground level of district served averages between elev. 3 and 6; highest point, near Ter Apel, being at elev. 43. Geological profile of well-field is illustrated. The nine initial wells, varying in depth between 243' and 276' pass through five clearly defined strata, chiefly sands of different sizes, and are equipped with intake filters where they contact the coarser sands, or gravel, mostly at full depth. The field was thoroughly tested in advance by numerous boreholes, etc. The water apparently is flowing in a north-northeast direction from the adjacent somewhat higher-lying province of Drenthe. About 1600 mil. gal. is expected to be the ultimate annual requirement. Down to 500', where the brackish layers begin, only sands are encountered. Studies of the action of the water on pipes of copper and lead revealed that the former was satisfactory, but that on lead pipe the protective layer was too slow in forming; lead pipe therefore cannot be safely used, unless coated with tin. As one community after another is getting its supply, the system is growing continuously. The pump-house has been constructed to its full ultimate size; but pumps are only put in as needed. Three filter houses are planned: but as yet only one has been erected. The water towers are being built only as required; in the first year, none was needed; the Stadskanaal tower is now in service and that at Oude Pekela, in course of erection. To date, construction has cost \$2,200,000; of which \$55,000, is from share capital; \$275,000, from interest-free advances by the province; and the remaining \$1,870,000, from loans effected through the provincial treasury, repayable in equal annual instalments over 40 yrs. Detailed schedule is given of the progress of the work from Jan. '32 to Dec. '36 accompanied by graphs of the numbers of draftsmen and overseers employed month by month in the respective operations of (1) erecting pumping station, (2) main laying, and (3) connecting up services. Rate at which main laying progresses is also given. Already 21,000 premises are connected, or in course of being connected; while about 45,000 more have yet to be brought in. For operation purposes territory is divided into districts, of which five already exist, with one inspector, one fitter, and one fitter's assistant to each. As the system grows towards completion, more districts will be organized and existing ones enlarged. There is a chief inspector at the head office. Supplies are handled by system which is outlined. Three sets of files are maintained; one for the correspondence etc. relative to the initial connection of each individual

premises; one for all other correspondence, and one for drawings. The rates in force are (1) a flat rate based upon the size of the dwelling, varying from 84 cents up to $7.70 quarterly and subject to (2) a surcharge if the consumption exceeds a certain limit. Industries and institutions are metered and pay only for what they use except that they have to guarantee a certain minimum consumption. The price varies from 73¢ per 1000 gal. for consumption not exceeding 6500 gal. per quarter down to 25¢ for consumption in excess of 500,000 gal. For premises partly domestic, partly industrial, there is a "mixed" rate. Where there is no industrial use and the plumbing is simple, no meter is installed. Only about 12% of the services are metered. Service pipes up to 130′ are laid free of charge; neither is there any charge for meter rental; interest, depreciation and upkeep on service lines and meter rental are included in the rate structure. There are no extra charges (such as for toilets or garden sprinklers). The figures quoted are those in force for the 44 communities who threw in their lot with the company in good time. The remaining communities will have to pay something more. The average consumption of water per connection, industrials included, is 2300 gal. per annum; the max. daily average, so far, has been 130 gal., and the max. hourly average, 10 gal. Water was first delivered in Aug. '34, when five communities had been connected. Very soon after, five more were connected. Water is now being supplied in 17 communities, about 83% of the possible consumers therein being connected. For the period Aug. '34 to Dec. '35 a loss was shown of $26,500. For '36, after making full allowance for depreciation etc., there was a profit of $6000, not a large sum, but a quite satisfactory token of future earnings and reflecting great credit on the work of the staff.

II. The Plant of the Provincial Water Company of Groningen. Ir. A. J. Kramer. The pumping station, illustration and plan of which are given, consists of a main hall about 43′ x 66′ to house the pumps, with two extensive wings, one on each side, for auxiliary equipment. Power is taken from the central electric supply. 8 motor-driven centrifugal pumping units (4 low-pressure and 4 high-pressure) have been installed and space is available for the remaining pumps which will be required. The pipe-gallery and heating plant are in the cellar. Specifications for the mechanical and electrical equipment were in great detail, so that each item was readily checked. Failure to attain guaranteed performance of pumps, motors, etc. carried heavy penalty, and substantial fulfillment of guarantee was attained.

The well water contains both iron and manganese and the government Bureau of Drinking Water Supply was called into consultation to devise the best form of treatment. An experimental plant (illustrated) was set up in which cylindrical tanks 4′ in diam. did duty as preliminary and final filters. The scheme evolved includes (1) intensive aeration, (2) preliminary filtration at rate of 10 ft. per hr., (3) aeration, and (4) final filtration at same rate as preliminary. Sand beds of both filters were 3′ in depth, sand in preliminary filter being rather coarser. The plans call for three filter buildings each of 160,000 gal. per hr. capacity forming three sides of a square of which the pump-station is the fourth side. Each filter building consists of two symmetrical halves, each of which has a capacity of 80,000 gal. per hr. For initial needs, one of these halves was enough to provide all the water required and that

was all that was built at first. The required area of 1080 sq. ft. is divided into unit filters of 360 sq. ft. each. The filter buildings, including the roofs and their supports are of reinforced concrete. Filter runs at full capacity are about 30 hrs. for the preliminary filters and about 1500 hrs. for the final filters. The limit set for loss of head is between 30″ and 40″. Filters are backwashed first with air (at 3 lbs. pressure) and then with water. Total water used in backwashing, including both preliminary and final filters, is about 2.7% of the water filtered. The backwashing system is described: eternit (cement-asbestos) pipe is largely used. Rapidly increasing consumption soon necessitated the construction of the second half of the first filter house, which was finished in July '36. There are nine wells at present in service, each connected by an 8″ branch with the suction main, the diam. of which increases by 2″ steps from 16″ to 22″, and which is laid at a slope of 1:1,000. The copper well strainers vary in diameter from 4″ to 8″. The slots are $1\frac{3}{8}$″ x $\frac{1}{16}$″, and they are surrounded with sand of $\frac{1}{16}$″ to $\frac{3}{16}$″ size. The basis laid down by the province for the distr. system was for an average of 10 gal. per hr. per connection, but not over 120 gal. per day: to which 25% must be added for future development; while for fire extinguishing, 4800 gal. per hr. is to be allowed with a max. of 40,000 gal. per 24 hr., the figure being reduced to 2800 gal. per hr. in some of the remote communities. The daily consumption actually reached an av. of 128 gal. on June 20, '36, on which same day the max. hr. of consumption almost reached the 10 gal. It seems as though an upward revision of the earlier consumption estimates may be necessary. Pressure drop is calculated by the Biegeleisen (metric) formula which gives satisfactory results:

$$h = 1.9 \times 10^{6} \times L \times \frac{Q \times 1.9}{D \times 4.9}$$

where h = loss of head in meters per km., L = length of pipe in km., Q = quantity flowing in litres per sec., D = pipe diam. in mm. The pipe sizes were carefully calculated to give the most economical balance as between pumping cost and amortization and upkeep of the pipes. The levels in the seven water towers are to rise and fall in unison, the high water mark in each to be at elev. 148 and low water at elev. 115. Cast iron predominates as being the most economical pipe material at time of purchase. Since '34, eternit (cement-asbestos) pipe has become a formidable competitor with cast and wrought iron. At end of '36 there were 215 mi. of cast iron mains of 4″ diam. and up, 7 mi. of wrought iron, and 3½ mi. of eternit. Great care was taken to ensure uniform protection by the asphalt coatings applied. No instance of any serious corrosion has as yet come to light. Since '36 the standard for asphalt coatings has become more exacting. As soon as the route of each new main is decided, samples of the various soils are taken for analysis and small weighed samples are buried at different points. Shortly before the pipe is laid the samples are taken up and examined for corrosion. Lengths of pipe have been buried at different locations all over the province and will be taken up and examined when pipes have to be laid in their neighborhood. Pipes are laid with the usual minimum cover of 40″. Piles had to be used for foundation only in the case of the first section of 20″ pipe leading from pumping station, owing to a

10′ layer of peat on the surface. Elsewhere the pipes lie on solid ground, peat where encountered being removed and replaced by sand. Concrete blocks are used to mark location of branches and bends. In corrosive soils, the pipes were surrounded by a layer of selected sand of at least 4″ thickness. Many details are given of the main laying including the siphons where the numerous canals have to be crossed. Service pipes are of "steam" quality wrought iron, asphalt-coated and jute-covered, and are connected to the main by a Morris main valve, except in clay soil with a 20″ length of tin-coated lead pipe in between. They are asphalt-coated internally also. The exterior asphalt coating is $\frac{1}{16}$″ in thickness; over this is wrapped asphalt-treated jute; two coatings of asphalt follow, and finally a paper wrapping. Joints are all made cold to prevent melting of the asphalt. Experience teaches that it is impossible to be too careful in securing perfect soundness of the asphalt coating. The Stadskanaal water tower, the only one of seven as yet in commission, is fully described. At the chosen site when the topmost peaty layer, 6′ or 7′ in thickness, was removed, a layer of fine sand 40′ (and probably more) in depth was encountered, upon which (after careful examination) it was considered perfectly safe to erect the 4300 lbs. per sq. ft. tower. Of a settlement of 4″ considered possible, only 2″ has been realized to date. The capacity of the tank is 238,000 gal. and the permissible difference in level, 33′. In the construction, the usual type of 8 circumferential columns and four central columns, with 2 sets of intersecting cross-stays between adjoining columns, has been departed from for economical reasons. The four central columns have been united into one and the cross-stays done away with, the circumferential beams being made heavier. This results in more simple construction without any sacrifice of rigidity, because the four floors supported by the circumferential beams prevent horizontal deflection of the latter. Similarly, by making the tank floor thicker, supporting joists were rendered unnecessary. The tank rests directly on the middle column and the 8 circumferential ones, the tank wall vertically over the latter. The concrete structure of tank and supports is entirely independent of the masonry shaft; any mutual stresses can be only horizontal. The cylindrical masonry wall external to the tank is supported by the tank floor which extends out to receive it. The placement of the columns is such that when tank is full, the bending moment inwards exerted by the tank floor is approximately balanced by the sum of the moment of the horizontal pressure outwards on the tank wall and the moment due to the weight of the external masonry wall on the projecting edge of the tank floor. The foundation slab is octagonal and is stiffened by a heavy ring of rectangular section on which the columns rest. The weight of the tower when filled with water amounts to 9,830,000 lbs. and equally distributed over the surface of the foundation slab amounts to 29.8 lbs. per sq. in. Cracking of concrete has not been observed. To prevent freezing of pipelines in the water tower gas radiators have been installed, capable of keeping the inside temperature above freezing. The cost of water tower, inclusive of plans, supervision, insurance during building, land and piping, was $53,900. (*fl.* 98,000).

The apparatus used for transmitting indication of the water level in the tower to the pumping station consists of a transmitter moved by a float. The system does not use any separate source of electricity, so that interruptions are

reduced to a minimum. In case of short circuiting alarm signals are provided.

III. Administration of Provincial Water Company of Groningen. F. A. Roos. Two considerations are postulated: (1) all factors essential to operation of the system must be recorded in sufficient detail and be easily available; (2) the administration must be concise. The administration personnel will consist of 10 people to cover 21,000 accounts; the system can be enlarged without difficulty to cover 45,000 connections. The activities are divided into 4 parts: (1) account administration, (2) account records, (3) tariff administration, (4) cashier's department. The administration is based upon a number system, which allows detailed information regarding capital expenditures, income and operating expenses, without undue amounts of work. The financial results of the business depend on the following classification: (1) Production costs, divided into: pumping costs, maintenance, and amortization; (2) distribution costs, divided into: operation cost of distribution, maintenance, amortization, and cost of acquisition; (3) general cost, divided into: diverse general costs and amortization; (4) interest charges. A detailed description of the system with illustration of forms of book keeping are given. During '36 an average of 14,500 connections were handled. An administrative cost of $3,740 (*fl.* 6,800) was required to cover collection of payment for water consumption. This included postage and office supplies. In practice 85% of the connections paid within the specified time. The remainder received a notice to pay within 4 days, otherwise a bill would be rendered increased by one guilder for extra administration. This reminder brings in an additional 10%. If the remaining 5% does not pay the collector, the patron receives a letter and on non-payment is notified that the bill will be placed in the hands of the company lawyer, who adds 15 guilders to the bill for his services, and the case is referred to the police court. Thus far the few unwilling patrons were forced by the court to pay. One month's grace is allowed. Court action is brought only when the city administration declares that the person involved is capable of payment. Of all the communities involved 83% of the population is connected. For each community a map is available showing the local connections.—*Frank Hannan and Willem Rudolfs.*

Plenty of Good Water at Low Cost. W. W. DeBerard. Eng. News-Rec. 119: 977 (Dec. 16, '37). The organization and plant of the Cedar Rapids, Iowa., Water Dept. are described. A modern filtration and softening plant of 12 m.g.d. capacity was completed in '30. Max. demand is 8.5 m.g.d. Recent analysis in Iowa and midwest cities, of prices charged for 3,000 cu. ft., an average 6-month bill, showed Cedar Rapids to be lowest at $4.25. Mid-point was about $7.50. City has commission form of government and water dept. is run as nearly like a separate utility as is possible under existing statutes. Costs are entirely paid from service revenue and transfers from water account to make up tax or other deficits are not permitted. Consequently, amortization is ahead of schedule through purchase of bonds before maturity. Services are 100% metered and department owns and maintains all meters. Experience has shown that meters usually run fast within 6–12 months after setting: practice, therefore, is to adjust meters to run 2% slow at time of setting.

All meters are overhauled after 7–10 yrs'. service. Testing procedure and record system are outlined. Except in case of damage due to negligence (freezing and hot water), city bears cost of testing, repairing and replacement. Meters on domestic services are read every 2 mo. and on commercial and industrial services every month. It is believed that good meters should last 50 yrs., if parts subjected to most wear are replaced. Some meters have been in service for 40 yrs. Pitometer survey in '25 showed extremely little leakage. Few mains are less than 6". All hydrants inspected in fall and those in congested-value district every 7–10 days esp. in cold weather. Map records of valve locations are maintained. Continuous inventory of materials is kept and physical inventory made once each year. About 30–60 lbs. (upper limit 200 lbs.) of activated carbon per mil. gal. is added to the Cedar River water prior to softening with lime. During year ended Mar. 31, '37, the hardness was reduced from 11 to 5.5 g.p.g., the chemicals used per mil. gal. being: lime, 1220 lbs.; alum, 235 lbs.; chlorine, 10.6 lbs; ammonia, 1.7 lbs. In addition, 38.4 tons of carbon (8 months) were used. After settling, pH value is reduced from 10.2 to 8.5 with carbon dioxide derived from the flue gas of an oil-burning heating unit. The carbon dioxide used averages 8.6 p.p.m. and the recarbonated water has a phenolphthalein alkalinity of 2–5 p.p.m. Algae growths on walls of carbonating tanks are controlled by use of 24 lbs. of copper sulfate per day. Some difficulty was experienced due to corrosion of the carbon dioxide scrubber, which consisted of a sheet steel shell lined with concrete. This unit has been replaced with 2 asbestos-cement units filled, respectively, with coke and excelsior. No corrosion has been observed in the galv. wrought iron pipe grid in the recarbonation tanks. Total income during '37 was $217,750 and net income $21,350. Total assets are $2,286,000, of which distr. system represents $1,277,400. The grounds are well landscaped and considerable attention is devoted to maintaining the plant attractive in appearance.—*R. E. Thompson.*

Report of the Water Analyst (Corporation of Madras, India) for '36. S. V. Ganapati. Tabulations of meteorological data and operating and analytical results are given and discussed. As in former years, the slow sand filters did not function efficiently. The quality of the delivered water, while epidemiologically safe, was esthetically unsatisfactory, complaints often being received regarding presence of leeches, worms and other animalcules in the tap water. Present method of operation, which consists of straining the water at high rate through thin layer of fine sand, does not remove these organisms. Many investigators have reported that slow sand filtration is unsatisfactory for Madras conditions and 2 remedies have been suggested: (1) Installation of percolating filters ahead of the existing slow sand filters. (2) Abandonment of present plant and installation of rapid sand filters, preceded by coagulation. Neither of these proposals have been acted upon, although tenders were invited. Filtered water is treated with 1.0 p.p.m. chlorine. Samples are examined for lactose-fermenting organisms in 60, 20, 10, 5, 1 and 0.1 cc. If results are negative in all but the largest portion, sample is considered of first class quality. The percentage of such first class samples and the bacterial count per cc. on agar at 37°C., 48 hours incubation, were, respectively,

as follows: filtered water, 12.5% and 605; chlorinated water, 79.2% and 359; water from distribution system, 41.3% and 505. Latter figures indicate that aftergrowths occurred during distribution. The water prior to filtration had a bacterial count of 797 and all samples contained lactose-fermenting organisms in 10 cc. or less.—*R. E. Thompson.*

Des Moines, Iowa, Annual Report of Water Works for year 1937. Officers of Board of Water Works Trustees of Des Moines are Vernon Denman, Chairman, and Dale L. Maffitt, Sec'y and Gen'l Mgr. Population of city based on '30 U. S. Census is 149,315. Gross income of works equalled $811,547, gain of 0.43% over '36. This amounted to $5.44 per capita, and $23.99 per service. Net income, exclusive of fixed charges and depreciation was $485,890, 59.87% of the gross, a decrease of 0.80% over '36. Operation costs exclusive of fixed chgs. and deprec. were $325,657, 40.13% of gross income, being an increase of 2.34% over '36. Per capita cost was $2.18 and $9.63 per service. The income per mil. gal. pumped was gross $161.97, net exclusive of fixed chgs. and deprec. –$96.97, and operation cost –$65.00. Total number of live services amounted to 33,826 an increase of 468 during year, of which 99.49% are metered. Services per 1000 population equalled 227, with 4.4 persons for each. System has 3,341 hydrants equalling 9 per mi. of pipe, main rental per hydrant being $18.65. 370.884 miles of pipe make up system, sizes ranging from 4" to 36", pressure range 38 to 118 lbs. Population per mi. of pipe equalled 403. Total consumption –5,010 mil. gal., a decrease of 6.37%. Daily av. was 13.727 mil. gal. with per capita of 91.94 gal. and 405.8 gal. per service. 72.88% of total is metered and billed, this does not include water used by city for fire, flushing and cleaning streets and sewers, park and building uses etc. 40.13% of operating revenue went to operation and maintenance, 14.17% to depreciation, 43.63% to interest and sinking fund, and 2.07% to invested capital. Water delivered is free of color, and objectional tastes and odors. Av. daily bacterial count on sample at pump station was 0.866 bacteria per ml., office tap sample was 1.02: all samples were free of coli-aerogenes group. Alk. of water is 243 p.p.m., iron content 0.44 to 0.60, chlorides 8, CO_2 15–30, pH 7.0 – 7.1, calcium content and magnesium content approx. 90 and 31 p.p.m. respectively, av. total hardness 317 p.p.m., max. 390 and min. 290 p.p.m. Normal rainfall is 32.04", for '37 was 26.43", a deficiency of 5.61". Several charts of daily results are shown.—*Martin E. Flentje.*

Annual Report, Bureau of San. Eng., Maryland State Dept. of Health, 1936. Abel Wolman and George L. Hall. 20 pp. (1937). The activities of the Bureau in the fields of water supply, sewage disposal, stream pollution, industrial waste disposal, industrial hygiene and oyster surveys are reviewed. As a result of federal financial aid, sanitation has been appreciably extended in the state: 75.2% of the population is now served by public water supplies, treated water being provided for 71.2%; 72.1% is served by sewerage systems and the sewage from 64.5% receives some form of treatment. Stream pollution has been considerably reduced. Sealing of abandoned coal mines is progressing and considerable reduction in acidity has been effected. Analyses have indicated that the acid reaching streams of western Maryland is in

excess of 200,000 lbs. per day, approximately 50% being from abandoned coal mines. Additional engineers have been assigned to the inspection of water and sewage treatment plants to stimulate the employment of chemical control and the making of uniform reports: good results are being secured. The flood of March, 1936, caused considerable difficulty. Hagerstown water treatment plant, on Potomac R., was flooded to depth of 10′. The protective earth embankment, top elevation of which is 5′ above the 1889 flood level, was topped by 2.25′. Plant was out of commission 2 weeks. Water shortage was not acute, mountain sources aiding in the emergency. At Hancock, the water rose to 57″ above floor of filter building and plant was shut down for 4 days. Water was withheld from consumers until adequate residual chlorine existed throughout distribution system. At one institution, water drawn from taps of new building, in which plumbing is entirely of copper, was green. Water supply, obtained from a well, was found to be highly corrosive and aeration and lime treatment was recommended. Grounding of electrical equipment to copper pipes may have been a factor. Disposal of distillery wastes continues to be the chief industrial waste problem. One plant experimenting with the use of the waste for hog feeding. Evaporators are used at several plants, "gumming" giving rise to more or less difficulty. The typhoid death rate was 1.6 and 2.2 per 100,000, inclusive and exclusive of Baltimore, respectively. The Baltimore rate was 0.9.—*R. E. Thompson.*

RATES

U. S. Court Paves Way for New Rate Basis. ANON. Eng. News-Rec., 120: 6 (Jan. 6, '38). President Roosevelt's historical cost basis for utility rate valuation has passed its first Supreme Court test, if not with victory, at least with clear indication that 40-yr.-old standard established with 1898 decision in Smyth vs. Ames is open to amendment. In 6 to 2 decision written by Chief Justice Hughes, court on Jan. 3 reversed Calif. Fed. Dist. Court decision setting aside gas rate schedule prepared by Calif. Railroad Comm. for Pacific Gas and Electric Co. and remanded case to lower court for determination as to whether or not proposed rates are confiscatory. Significance of decision lies in fact that railroad commission based its findings largely on money invested. By instructing lower court to confine its findings to question of confiscation, Supreme Court opened way for finding that value based on actual investment rather than reproduction cost will not result in confiscation. —*R. E. Thompson.*

Indianapolis Water Case Back to District Court. ANON. Eng. News-Rec., 120: 6 (Jan. 6, '38). Indianapolis Water Co. rate case, long the subject of contest in lower courts, was sent back to dist. court by U. S. Supreme Court on Jan. 3 for further hearing and for decree based on experience, since dist. court's former findings, in operating company under rates set by Indiana Public Serv. Comm. The Dist. Court had set value with respect to which it held existing rates were not confiscatory and declared that value would hold for reasonable time in future. By time case came to be decided in Court of Appeals many months had elapsed and latter court, while declining to overrule lower court, observed that speculation as to future conditions had changed

to experience and noted that there had been continual rise of commodity prices in intervening months. On this indication of belief that value should be increased or that rates might now be declared confiscatory, company took case to Supreme Court.—*R. E. Thompson.*

Washing of Private Cars. ANON. Surveyor, 92: 250 ('37). This is an account of a case in which a consumer was tried under the Waterworks Clauses Act of 1863, which prohibits the use of the domestic water supply for the washing of private carriages. The case was adjourned for further legal argument.—*H. E. Babbitt.*

Water Rates to Outside Consumers. ANON. Can. Engr., 73: 14: 18 ('37). Data regarding Ontario municipalities collected by C. D. Brown and distributed through Water Works Information Exchange of Canadian Section, A. W. W. A. are given.—*R. E. Thompson.*

HEALTH AND HYGIENE

Endemic Fluorosis in the Madras Presidency. H. E. SHORTT, G. R. MCROBERT, T. W. BARNARD AND A. S. MANNADI NAYAR. Ind. J. Med. Res., 25: 553 ('37). Occurrence of this condition in Madras Presidency (India) has been recorded in preliminary paper by Shortt, Pandit and Raghavachari (cf. J. Amer. W. W. Assn. 30: 181 (Jan. '37)). Present account is more complete description based on careful investigation of 10 cases from affected area admitted to hospital for this specific purpose. Cases were chiefly in advanced stage of disease and description, therefore, applies more especially to individuals who have been subjected for periods of 40 yrs. or more to influence of drinking water containing comparatively large amounts of fluorine compounds. Systematic clinical description of cases is given followed by description (illustrated) of bony changes, as shown by radiology, which account for many of clinical manifestations, together with an account and tabulated results of biochemical investigations of blood and urine. In addition, in preliminary field investigation, earlier manifestations of disease, particularly mottled tooth enamel in children, were studied. Search of literature has failed to reveal account of fluorine intoxication comparable to that here described, either in area affected or in severity. Mottled enamel among children, which has very high incidence in area, is especially characteristic of permanent but also occurs in deciduous teeth when fluorine content of water is especially high. Latter indicates that very prolonged exposure is not necessary to cause this defect, provided fluorine content is high. Usual course in permanent teeth is that enamel loses its glistening appearance and becomes dead white like chalk, in one of 3 forms: (1) horizontal banding, (2) more or less centrally placed areas or (3) irregular patches. If consumption of the water continues, whiteness is replaced by chocolate-colored markings occupying exactly same areas. All these appearances are best shown by central upper incisors but any or all of teeth may be affected. Tooth defects seem to be confined to these color effects and there appears to be interval, extending from childhood to about 25 to 30 yrs. age, during which few or no ill effects are exhibited. At about 30 yrs. first symptoms of intoxication appear, evidenced by recurrent tingling sensa-

tion in limbs and over body in general. Pain and stiffness next appear, especially in lumbar region of spine but also involving dorsal and cervical regions. Stiffness increases until entire spine, including cervical region, appears to be one continuous column of bone, producing condition of "poker back," and there is stiffness of various joints. Bony skeleton of thorax is markedly affected and ribs become rigidly fixed at junction with spine. Breathing, as result, becomes entirely abdominal, while chest assumes barrel-shaped outline flattened anteriorly. By time this condition is reached, individual is between 30 and 40 yrs. of age and later and final stages are imminent. Patient is finally completely bed-ridden, mental powers being unimpaired. Death, when it occurs, is usually due to some intercurrent disease. In 6 of cases fluorine content of urine was much above normal: in only 3 cases was fluorine demonstrated in blood. Bibliography of 63 references is appended.—*R. E. Thompson.*

Fluorine Found in Water of Chicago Suburb. ANON. Eng. News-Rec., 119: 1032 (Dec. 23, '37). Studies in Elmhurst, Ill., revealed high mottled enamel index in teeth of children and fluorine content in water supply of 2 p.p.m. These conditions are believed to be typical of nearly 100 communities in the area and may result in abandonment of present deep well supplies in favor of supply from Lake Michigan.—*R. E. Thompson.*

The Occurrence of Mottled Enamel of Teeth in Alberta and Its Relation to the Fluorine Content of the Water Supply. OSMAN J. WALKER AND ELVINS Y. SPENCER. Can. J. Research, 15: B: 305 ('37). In several parts of Alberta mottled enamel in mild form is endemic, especially in area surrounding Lethbridge and in area south of Red Deer. From examination of more than 250 samples of water from different parts of province, a relation was found between high fluorine content of water supply and prevalence of mottled enamel.—*R. E. Thompson.*

CROSS CONNECTION CONTROL

Special Equipment Cross-Connections. ARTHUR V. HARRINGTON. J.N.E.W.W.A. 51: 3 (Sep. '37). Swimming pools through the filling connection either directly to pool or to re-circulating pump may be an undesirable cross-connection to water supply system. Solution chlorine feed into sewage, sewage ejectors, apparatus for adding water to vats without splashing as in chemical industries, and automatic addition of water to scrubber spray piping of certain types of air conditioning apparatus are other hazards existing in the av. community. One item of special equipment described was the gasoline storage and feed system of an airport. Tank and feed equipment was entirely underground and pressure for feeding gasoline was obtained through entrance of water from supply main into bottom of tank, the gasoline then floating above the water. A new method of feeding an insecticide of spray type is mentioned in which cartridge containing chemical compound is attached to sprinkling hose, which under certain conditions might result in entrance of chemical to water supply.—*Martin E. Flentje.*

Cross-Connection Elimination Stimulated in Los Angeles. ANON. Eng. News-Rec., 119: 561 (Sep. 30, '37). According to annual report of R. F. Goudey, 575 cross-connections were removed or protected by vacuum breakers in Los Angeles last year. Double check-valve installations are inspected every 6 months. Owners and builders of new buildings are warned of dangers of cross-connections and attention is drawn to ordinance requiring removal of any such connection installed. At least 40% of intended cross-connections have been prevented in this way.—*R. E. Thompson.*

Plumbing Fixtures Subject to Back-Siphonage. L. K. SHERMAN. J.N.E.W.W.A., 51: 266 (Sep. '37). Potential dangers from back-siphonage in various types of plumbing equipment are pointed out. Toilet bowls and urinals, fixtures with under-rim inlets and types of special fixtures are enumerated and briefly discussed.—*Martin E. Flentje.*

What Interest Has a Water Purveyor in Interior Plumbing Systems in Relation to Cross-Connections. M. W. COWLES. J.N.E.W.W.A., 51: 261 (Sep. '37). The effort made to provide safe drinking water in the mains is ineffective if water delivered from taps within a building is not equally safe at all times. Numerous possibilities for contamination of tap water do exist in buildings. Author uses organization he is connected with to illustrate effectiveness of co-operation with consumers having cross-connection and defective plumbing on premises. This work is aided by a N. J. Health Dept. regulation requiring installation of approved protective devices on cross-connected mains. Continued and re-inspection of auxilliary supplies and mains and interior plumbing is necessary for success.—*Martin E. Flentje.*

TREATMENT—GENERAL

Progress During '37 in Treatment of Water Supplies. N. J. HOWARD. Eng. Cont. Rec., 50: 105:41 (Dec. 29, '37). Developments in the fields of pollution control, filtration, coagulation, softening, corrosion reduction, chlorination, taste and odor control, etc., are reviewed. At no time during recent years has pollution abatement received greater attention than during '37. Legislative restrictions have been imposed in several instances. The recent cyanide pollution of the Niagara River, which caused the death of over 500 million fish, will probably result in a revival of the investigations of boundary water pollution by the International Joint Commission. In field of filtration, chief interest centered in use of underdrainage systems other than perforated pipe type, increased use of "anthrafilt" in lieu of sand and wider adoption of surface and sub-surface washing systems. Increased attention is being given to the newer coagulants and to compounds which increase coagulation efficiency, i.e., bentonite, sodium silicate, ferric chloride and activated alum. Softening again made definite headway. As result of water-borne disease epidemics, chlorination is being more widely adopted abroad, notably in Great Britain. For taste and odor control, while ammonia-chlorine treatment continues to be increasingly employed, the use of activated carbon stands out pre-eminently. Approximately 1000 treatment plants are now employing carbon at some stage in the purification process. The average dosage used is between 20 and 21 lbs.

per mil. gal. Increasing attention is being given to super-chlorination of the raw water followed by application of activated carbon. The presence of fluorine in water supplies, its effect on the human system and methods for its removal were the subjects of a number of investigations. Activity continued in prohibition and elimination of cross connections. In spite of current knowledge, moderate-sized outbreaks of water-borne typhoid and para-typhoid occurred during the year. Until sterilization of water and pasteurization of milk are made compulsory or adequate steps are taken to prevent pollution of water supplies sporadic outbreaks can be expected.—*R. E. Thompson.*

Meeting of the Section on Water Chemistry during the Convention of the Society of German Chemists. Gesundheits Ingenieur. **60**: 35; 543 (1937). This report gives only abstracts of papers read at meeting in Frankfurt a.M., July 6 '37, but it shows the problems that are before German Water Chemists. Dr. Nachtigall discussed Water Chemistry and the four year plan in which he mentioned the necessity of replacing metals by products produced at home, reuse of wastes and the conservation of present values through reduction of corrosion. Similar problems are treated by Dr. Heilmann in the field of sewerage and sewage treatment. Dr. Schilling reports on new experiences in the treatment of drinking water by the use of magno-filters. These filters contain a material produced by burning dolomite. They can be used to reduce the acidity in the water and also to remove iron. Although the equilibrium produced in the water cannot yet be fully explained it was found that waters that passed through a magno-filter do not corrode the pipe lines. Other useful properties are ascribed to this material. Dr. Stooff reports that it removes arsenic from the water, Dr. Sartorius found it will eliminate humin materials, and Dr. Haase iron and manganese, from a swimming pool supply. Dr. Strohecker introduced a new relation between the pH value of the water and its carbonate hardness for the determination of the agressive property of water. Dr. Kroke explained automatically recording and regulating apparatus, especially for the dosing of chlorine.—*Max Suter.*

Titanium Salts in Water Purification. W. V. Upton and A. M. Buswell. Ind. Eng. Chem. **29**: 870 (Aug. '37). Tests were made with pure titanium sulfate and with extract from mineral, ilmenite, containing both titanium and ferric sulfates. Reagent was hard to feed in solid state and hydrolyzed readily in feed solution unless kept concentrated. Titanium reagents gave good coagulation from pH 2.9 to 8.2 and flocs settled well except at extreme lower end of range. No residual titanium was found above pH 3.5. Dosages of 10 g.p.g. of aluminum sulfate, titanium sulfate or ilmenite extract removed only 0.5 p.p.m. of fluoride from water containing 4.5 p.p.m. pH had little influence. Titanium sulfate gave better color removal than aluminum sulfate or ferric sulfate. At low temperatures (1.5 to 4.0°C.) 2 g.p.g. of titanium sulfate at pH 8.5 yielded floc in one-half hour while same amount of aluminum sulfate gave only opalescence. With mixtures of aluminum and titanium reagents totaling 2 g.p.g. at low temperatures, tendency to pinpoint floc was less as titanium ratio increased.—*Selma Gottlieb.*

Adsorption of Fluoride from Salts by Alum Floc. C. S. Boruff, A. M. Buswell and W. V. Upton. Ind. Eng. Chem. 29: 1154 (Oct. '37). Cation associated with fluoride in water greatly affects completeness of its removal by alum floc. Alum treatment is not effective in defluorination of many natural waters since fluoride is adsorbed much less effectively when present as calcium or magnesium fluoride than when compound is sodium fluoride. Removal of calcium and magnesium by zeolite is not sufficiently complete to convert small amounts of fluoride (4 p.p.m.) to sodium fluoride and therefore zeolite softening before alum treatment does not materially improve fluoride removal.—*Selma Gottlieb.*

Sterilizing Filters for the Home and Small Filter Installations. Hayo Bruns. Gas-u. Wasser. 80: 502 ('37). Many types of commercial filters are available for single houses and small settlements. Those filled with sand of a grain size of 1 mm. diameter retain only about 10 to 20% of the bacteria, although they are effective in retaining oxidized iron. With a grain size of 0.5 mm. about 50% of the bacteria are retained, but the loss of head is greatly increased. Filters fitted with marble are supposed to reduce acidity but do this only if a long period of contact is available. The marble particles also get covered by iron rust and thereby lose activity. Magno mass does not seem to have these disadvantages. Activated carbon will reduce taste and color, but remove but a few bacteria. Filters filled with diatomaceous earth or with asbestos filter plates are bacteriologically satisfactory, but even these require periodic washing or even replacement.—*Max Suter.*

Swimming Pool at Earl's Court Exhibition Building. Anon. Engineering (Br.) 144: 473 (Oct. 29, '37). Large part of the arena of the central hall is occupied by a swimming pool, 195' x 95'. The water is to be aerated, and chemically and bacteriologically treated, and 800,000 gal. (Imp.) can be circulated every six hr. through the four large filters. Interesting feature of the construction of the pool is movable steel false bottom which can be raised to provide a complete temporary floor on the arena area, over the pool.—*H. E. Babbitt.*

STERILIZATION

The Stability of Hypochlorite Solutions. R. Laurnagaray. Bol. Sanitario (Buenos Aires). 1: 526 ('37). An important study of the chlorine content of hypochlorite solutions kept under different conditions, namely: (1) In the original vessel at room temperature; (2) in dark glass bottles, partly filled, at room temperature; (3) in colorless bottles under similar conditions; (4) in dark glass bottles and (5) in colorless bottles, filled and at room temperature, (6) in colored bottles, with varying amounts of liquid, and at a temperature higher than that of the surrounding atmosphere. The results of these tests are given in protocols and graphs, but they may be summarized:—In the original (uncolored) bottles kept in the dark or in dim diffused light at ordinary temperature, the original strength of active chlorine was retained for 4 months, after which there was a gradual loss, so that at the end of 18

months there was a reduction of 20%. If kept in colorless bottles exposed to diffuse sunlight the loss is rapid and particularly if the bottles are only partly filled. If kept at a temperature of 34°C. there is a loss in four months of 30% of available chlorine.—*B. H.*

The Oligodynamic Action of Silver. HANS FROMHERZ AND JOSEF HEISS. Angew. Chem. **50**: 679 ('37). Experimental evidence shows that the oligodynamic action of silver is due to silver ions in concentration greater than 2×10^{-11} molecule/liter. The silver ions either come directly from silver compounds or are liberated by localized currents in concentration cells on superficially oxidized or impure silver parts.—*R. E. Thompson.*

Chemical Water Treatment in Switzerland. H. GUBELMANN. Schweiz. Ver. Gas- u. Wasserfach., Monats-Bull. **17**: 121 ('37). A review of Swiss practices. Conclusions: Sterilization of water with chlorine is of greatest utility; low chlorination is sufficient and no additional chemicals for clarification are generally required. Pre-ammoniation is beneficial in avoiding taste and odor. Prevention of contamination of water source is of primary importance. Daily testing of product, preferably by recording instruments, is advocated. If economically sound, ozonization is satisfactory; for small installations, the electro-catadyn process has possibilities.—*R. E. Thompson.*

Bactericidal Power of Chlorine in Disinfecting Water by the Werden Method. L. I. Los. Inst. recherches sci. union soc. croix rouge et croissant rouge (Saratov), Referaty Nauch Rabot Inst., No. **8**: 16 ('36). Chlorination with vigorous mechanical agitation possesses no advantage over chlorination without agitation for river and well waters, treated with 0.02–0.08 p.p.m. of chlorine, and increases but slightly (8–10%) the effectiveness for distilled and tap waters, treated with 0.01–0.06 p.p.m. Treatment with small amounts of chlorine (concentrations which cannot be detected in water immediately after addition) is not very effective and is not recommended for sterilization of contaminated water.—*R. E. Thompson.*

Sterilization of Water in the Colonies. (French) PIERRE PAILLAS. Eau, **30**: 93 ('37). Recommended chemical methods of treatment include use of solution consisting of 1 gram iodine and 2 grams potassium iodide to 200 cc. of water, which is added to the water to be sterilized until faint but distinct "light rum" color appears. If color disappears in 20 minutes a little more of the solution should be added. Finally, a drop of 20% sodium hyposulfite solution is added with agitation and the water is ready to drink. Usually, 1 drop of Javel water will sterilize 3 liters of water, but procedure is not entirely dependable. If one desires to use potassium permanganate as sterilizing agent, just enough of solid should be added to give rose-colored solution. If color disappears after 20 minutes, more permanganate must be added. If this color is retained for 20 minutes, color is dissipated with drop of sodium hyposulfite. Of course, boiling is also a safe procedure.—*R. E. Thompson.*

FILTRATION

Construction of a Modified Slow Sand-Filtration Plant at Greenfield, Mass. H. L. FIELD. J.N.E.W.W.A., 51: 173 (Jun. '37). The water supply for Greenfield, Mass. is taken by gravity from small reservoirs on Glen Brook, a tributary of Green River; and from a pumped ground water supply in Green River valley. The reservoir water is generally clear with zero or very low turbidity and color varying from 0 to a max. of 15, and with an av. total hardness of 41 p.p.m. During time of storms and for short periods turbidity has gone up to 150. Purification plant placed in operation Nov. 1, '35 consists of a 2-unit coagulating basin with provision for chemical treatment when necessary with retention in each unit of 9.6 hr.; 2 slow sand filter units each 0.2 acres in area operated at 5 mil. gal. per acre per day; 550,000 gal. capacity clear well; brick filter house; piping and appurtenances. Filters have 12" of gravel, —7" of 1½" to ¾", 3" of ¾" to ¼" and 2" of ¼" to 12 mesh with 36" of sand of 0.36 mm. effective size and unif. coeff. of 2.5. Rate controlled by rate of flow controllers. In first 208 days of operation with av. rate of filtration of 1.56 m.g.d., both filter units had been scraped twice, and yield between scrapings had been: for 136 days, 212.7 mil. gal. and 72 days including flood period, 112.6 mil. gal. Total cost of plant and 1¼ mi. of 20" c.i. pipe line was $176,710 of which $89,483 was furnished for labor by F.E.R.A.—*Martin E. Flentje.*

Operating Experiences at the Salem and Beverly Filtration Plant. ROBERT P. JOHNSON. J.N.E.W.W.A., 51: 185 (Jun. '37). Paper describes operation of new filtration plant placed in operation Oct. 27, '35 (cf. abstract 29: 570 (Apr. '37)). Average color of raw water had increased prior to operation of plant to 40, four times color before 1895. Odors caused by algae, organic matter and decomposition of growth on reservoir bottom exposed during periods of extremely low water levels, became yearly more severe. Bacterial count and conc. of coliform organisms had also increased. The 8-1 m.g.d. gravity filter units have perforated underdrains, with 18" of gravel of sizes: 7" of 2½" to 1½", 4" of 1½" to ¾", 4" of ¾" to ¼", 3" of ¼" to 12 mesh; covered by 30" of Plum Island sand of 0.35 mm. effective size. Water not difficult to coagulate, good floc forming in 5 min. Alum only coagulant used on color range of 24 to 70 p.p.m. so far experienced, dose from 1.10 to 1.78 g.p.g., optimum pH range for coagulation found to be broad, from 5.4 to 6.7. Prechlorination used for several weeks resulted in larger floc formation. Activated carbon successfully used for taste and odor control, not found to be aid to coagulation. Sand size has not changed appreciably but filter runs have averaged only 15.3 hr. Wash water equalled 4.6%. Ammonia-chlorine treatment with ratio of Cl to NH_3 of 4 to 1, later 2 to 1, was successfully used in eliminating coli-aerogenes in distribution system. Color reduced through plant from av. of 42 to 8, pH raised to 8.4, 20° bacterial count reduced from av. of 116 to 0, and 37° count from 36 to 1 per cc., av. of most probable number of coli-aerogenes was 20 per 100 cc. in raw water and 0.03 in delivered water. Total operating cost averaged $15.04 per mil. gal. with $4.59 for chemicals, $3.02 for labor, $4.62 for power and light, each per mil. gal.—*Martin E. Flentje.*

Water Supply of Northborough, Mass. and Its Improvement. R. S. Weston. J.N.E.W.W.A., 51: 248 (Sep. '37). To correct taste, odors, color and pollution the Town of Northborough, Mass. instituted improvements totaling $126,461 in cost. Work consisted of facilities for chemical coagulation, settling in basin 88′ x 50′ with cap. of 0.395 m.g., 2 covered slow sand filters of conventional design each 50′ x 29′ equipped with controllers, rate of flow and loss of head indicators and operated at rate of 5 m.g.d. per acre; addition of soda ash to minimize corrosion, 0.5 m.g. standpipe 45′ in diam. and 42′ high and connecting mains. Plant is operated automatically through clear well and float valves. Color is reduced from 70 to 5 p.p.m. and less, with plant effluent free of tastes and odors.—*Martin E. Flentje.*

Rapid Gravity Filtration Plant. The Central Control Table. Anon. Surveyor (Br.) 92: 322 (Sep. 10, '37). Each filter in a battery has its own control table. The tables are constructed of steel framework with encased side panels of polished marble and a 1½″ thick top of the same material. Each table is connected by a small pipe to the sourse of hydraulic power and to different valve cylinders which are to be controlled from the table.—*H. E. Babbitt.*

Edinburgh Water Works Extensions. Additional Sand Filters Installed. Anon. Civ. Eng. (Br.) 32: 341 (Sep. '37). Two slow sand filter units are to be added to the existing five units, at Fairmilehead, each with a nominal capacity of 1.5 m.g.d. (Imp.).—*H. E. Babbitt.*

Cleaning Filter Beds with Sulfur Dioxide at Montebello Filters, Baltimore, Md. Anon. Taste & Odor Control, 3: 12 (Aug. '37). Water in the filters was drawn down to the gravel layer, the sulfur dioxide added (as liquid into the effluent pipe) and the water level then restored to that of the top of the sand bed. Three applications of sulphur dioxide were made, the concentrations being 0.20, 0.63 and 0.97% and the contact periods 16, 21.5 and 18 hours, respectively. After the third treatment the gravel was bright in appearance and the adhering iron and manganese was readily removed by backwashing. The treatment also appeared to be effective in breaking up mud balls. Total cost was $190.26, equivalent to $1.18 per cubic yard.—*R. E. Thompson.*

New Use for Windshield Wiper. Anon. Eng. News-Rec., 119: 1027 (Dec. 23, '37). The Cedar Rapids, Iowa, purification plant is equipped with observation well in which any slight turbidity in treated water may be detected. Four drop lights (marine type) are located near bottom of well, which is 8′ deep (water depth) and has white and black tile floor. Condensation is removed from lower side of glass cover by means of wiper which is revolved by handwheel attached above glass to brass rod threaded through hole which is protected by gaskets.—*R. E. Thompson.*

CHEMICAL

Detection and Estimation of Minute Amounts of Fluorine by Means of the Etching Test. Earle R. Caley and Jose M. Ferrer, Jr. Mikrochim.

Acta, 1: 160 ('37). The disadvantages of carrying out the etching test by previous procedures are pointed out and new apparatus is described which is cylindrical and can be made quickly on lathe from cylinder of cast lead. Flange is provided on lower part so that entire apparatus can be handled with tongs and can be placed on ring of an oil bath or inserted in the hole of a metal heating block. Upper surface of lower part is ground flat and polished so that microscope cover glass will fit tightly when the heavy top piece is placed upon it. As little as 0.05 mg. calcium fluoride can be detected easily in very short time. Relative etching is rough measure of fluorine content of sample.—*R. E. Thompson.*

Solubility Equilibria of Sodium Sulfate at Temperatures from 150 to 350°. Part III. *Effect of Sodium Hydroxide and Sodium Phosphate.* W. C. Schroeder, A. A. Berk and Alton Gabriel. J. Am. Chem. Soc., **59:** 1783 (Oct. '37). Third paper in series presenting results of cooperative investigation between Eastern Exp. Sta. of Bureau of Mines and Joint Research Committee on Boiler Feed-water Studies. Investigations of effect of sodium hydroxide and trisodium phosphate on solubility of sodium sulfate were made in redesigned bomb, opening at both ends and sealed by metal-to-metal contacts without gaskets. Sampler is enclosed in bomb to ensure sampling at operating temperature. Bomb has total volume of approximately 230 cc. with sampler in place. Changes were made to facilitate sampling of solid phases. Solubility of trisodium phosphate in water was found to reach maximum at 120°C. where transition to monohydrate occurs. Above 215° trisodium phosphate is anhydrous, and above 250° solubility is very low, approaching zero at 350°. At 150°, addition of sodium hydroxide (up to 30 grams per 100 grams of water) causes rapid decrease in solubility, at 250° slight decrease, and at 350° slight increase. At 150° addition of trisodium phosphate to solution saturated with sodium sulfate causes almost linear decrease in solubility of sodium sulfate, with evidence of new solid phases other than sodium sulfate at trisodium phosphate concentrations above 60 grams per 100 grams of water. At 200° and above, increase in trisodium phosphate concentration causes increase, usually slight, in sodium sulfate solubility up to certain point and then more or less sharp decrease in solubility. Two double salts have been identified at 200°, $Na_2SO_4 \cdot 2Na_3PO_4$ (I) and $Na_2SO_4 \cdot 5Na_3PO_4$. At 250° (I) forms solid solutions with trisodium phosphate or with other double salts of the two original constituents. At 150° and 250° addition of sodium hydroxide to the sodium sulfate-trisodium phosphate—water system lowers solubility of both sulfate and phosphate, (I) being formed at 250° at lower phosphate concentrations. At 350° sodium hydroxide markedly increases solubility of sodium sulfate and trisodium phosphate. Results of examination of solid phases with petrographic microscope are presented. **Part IV.** *Comparison of Evaporation and Equilibrium Solubility Values.* W. C. Schroeder, A. A. Berk and Everett Partridge. Ibid., p. 1790. To determine accuracy with which equilibrium values can be applied to system undergoing evaporation, amount of sodium sulfate in solution from which steam is being removed was compared with amount present at equilibrium at 200, 250, 300 and 350°. Test solution was placed in evaporation bomb and three or four samples drawn during evaporation of water at desired tempera-

ture. If sodium sulfate is only solid phase, supersaturaton does not occur in pure solutions or in presence of dissolved sodium carbonate, hydroxide or phosphate. If solid phase is a double salt of sodium sulfate with sodium carbonate or trisodium phosphate, marked supersaturation may occur. Sodium sulfate and sodium chloride formed heavy scales in region in which solubility increases with temperature, possibly due to vaporization of water at heat transfer surface with consequent throwing out of solution of considerable amounts of solid. Evaporation tests furnished additional information on solubility of sodium sulfate, and except where supersaturation results from slow attainment of equilibrium with respect to double salts, results are in agreement with previous data.—*Selma Gottlieb.*

Determination of the Total Alkali Metals and the Microgravimetric Determination of Sodium as Sodium-Magnesium-Uranyl Acetate with a Note on the Microanalysis of Mineral Water. R. Dworzak and A. Friedrich-Liebenberg. Mikrochim Acta, 1: 168 ('37). In this paper, only lithium, potassium and sodium are considered. It is quite common practice to weigh combined alkali as chlorides. Experiments here described show that this is permissible with sodium and potassium but lithium chloride is so hygroscopic that results are likely to be too high. The chlorides can be heated to 200°C. without loss by volatilization. The sulfates of lithium, potassium and sodium are not appreciably hygroscopic and can be heated to 700°C. without loss. It is preferable, therefore, to weigh total alkali as sulfates. If weighed as chlorides it is well to dry at 200° and as sulfates at 700°. To determine total alkali in mineral water, it is recommended to take only 5 cc. of sample, remove silica by evaporation with hydrochloric acid, other cations by treatment with lime water, excess reagent as carbonate and finally as oxalate in usual way, evaporate with sulfuric acid and weigh sulfates after heating to 700° in electric furnace. Numerous experiments on determination of sodium as sodium-magnesium-uranyl acetate ($NaMg(UO_2)_3(AcO)_9 \cdot 8H_2O$) showed that for microchemical work, Kahane's reagent containing ethyl alcohol is best and optimum sodium concentration is 0.025–0.3 mg. sodium per cc. It is desirable to use only slight excess of reagent and to cause precipitate to form slowly. Under these conditions, relatively large crystals are obtained which are purer and less soluble than those obtained by rapid precipitation. Results are good in presence of twice as much potassium, 0.25 times as much lithium, 11 times as much calcium or barium, an equal quantity of iron or phosphate and 8 times as much silica. Thus direct determination of sodium as triple acetate is possible in most samples of mineral water. Results for total alkali and sodium are nearly as good as those obtained in usual macroanalysis.—*R. E. Thompson.*

Rapid and Accurate Method of Determining Silica in Sands and Aluminous Silicates. P. Haniset. Ing. chim., 20: 117,153 ('37). Procedure is described in which hydrated silica is precipitated gradually by adding solution of melt obtained by alkali fusion to acid which is buffered with sodium phthalate. Precipitate is boiled under reflux condensation with repeated addition of xylene in automatic device which gradually effects removal of acid solution and leaves silica under nearly pure xylene. Xylene makes silica less soluble and more easily filterable.—*R. E. Thompson.*

LABORATORY EQUIPMENT

A Buret-Filling Device for Portable Reagent Reservoirs. NEIL E. RIGLAR. Ind. Eng. Chem.-Anal. Ed. 9: 436 (Sep. '37). Modification of usual arrangement for transferring liquid from non-elevated bottle to buret with compressed air from hand operated rubber bulb. Delivery tube passes into bottle through tube connected to compressed air supply. Latter tube expands at lower end into bulb with capacity slightly greater than that of buret, and closed with valve made by grinding short glass rod into seat formed by sealing 4 mm. tubing to lower end of bulb. Application of compressed air seats valve and forces liquid through delivery tube into buret. May be applied to bottle of any size.—*Selma Gottlieb.*

Apparatus for Testing Crushing Strength of Granules. E. F. HARFORD. Ind. Eng. Chem.-Anal. Ed. 10: 40 (Jan. '38). Crushing strength of granules is detd. in apparatus consisting of lever horizontally pivoted in center. Applied force acting upwards on one end is direct function of granule resistance to crushing on other end. Load is applied to lever by string winding on reel. Spring balance is connected to reel system to measure load. In crushing of 15 or 20 granules for single sample, max. deviation from av. was ±8% and ±6% respectively. Capacity of instrument was 2000 or 4000 grams depending on lever ratio.—*Selma Gottlieb.*

A Sensitive Glass Electrode of Durable Form. ANGUS E. CAMERON. Ind. Eng. Chem.-Anal. Ed. 9: 436 (Sep. '37). A 2 cm. bulb of fairly heavy wall is blown from 1 cm. Corning 015 glass at 45° angle to tube. Small spot on upper side near stem is heated and sucked in to form bulb within bulb. After cooling somewhat, same procedure is followed at spot on bottom, opposite top opening, bulb being sucked in until it touches inner bulb and forms flat membrane, and then center heated until glass melts through and hole opens out. Electrodes of this type have been used continually for 6 mo. in routine measurements, replacing ordinary bulbular form with av. life of 1 wk.—*Selma Gottlieb.*

HYDRAULICS AND HYDRAULIC ENGINEERING

The Discharge of Small, Submerged, Sharp-edged Orifices. R. J. CORNISH. J. Inst. C. E. (Br.) No. 1: p. 147 (Nov. '37). The downstream head on a submerged orifice has a considerable influence on the coefficient of discharge, provided the Reynolds number is less than 3,500. Above this value of the Reynolds number the effect of the downstream head is negligible provided that the dimensions of the orifice are small compared with those of the channel into which it discharges. There is a definite tendency, especially marked at low Reynolds numbers, for the coefficient of discharge to be lower with warm water than with cold. A rise in temperature from about 50° to 95°F. results in a decrease in the coefficient of discharge at the same Reynolds number.—*H. E. Babbitt.*

Varied Flow in Open Channels of Adverse Slope. A. E. MATZKE. Trans. A. S. C. E. 102: 651 ('37). A canal may be said to possess adverse slope if its bottom rises in the direction of flow, and when the bottom falls in the direction

of flow a channel possesses a sustaining slope. The general equation of flow for channels of adverse slope is

$$l_{2-1} = \frac{y_o}{S_o}\left[-(N_2-N_1) + (1+\beta)\left\{B'(N_2) - B'(N_1)\right\}\right]$$

in which l_{2-1} = the distance between section 1 and 2; y = a parameter denoting variable depth of flow; y_o = normal depth of flow; S_o = sustaining slope of a channel bottom; $N = \frac{y}{y_o}$; β = the relation between the bottom slope, S_o, and the critical slope, S_c; B′(N) is the varied flow factor for adverse slope. 1 and 2 are subscripts denoting the sections at which a characteristic or function is applicable. Values of B′(N) are tabulated and practical examples are solved.—*H. E. Babbitt.*

The Reduction of Carrying Capacity of Pipes with Age. C. F. Colebrook. J. Inst. C. E. (Br.) No. 1: p. 99 (Nov. '37). After water mains have been in service for some time their hydraulic resistance usually increases owing to growths or deposits on the internal surfaces, and unless the head is increased the flow falls off until eventually cleaning or replacement is necessary. The relation between the various factors involved can be expressed as follows:

$$d^{\frac{5}{2}} = \frac{1.2Q}{\beta\sqrt{gi}}$$

in which: d = diam. of the pipe, in ft.

Q = rate of flow, in cu. ft. per sec. after time T.

T = time that the pipe has been in service, in years.

g = 32.2 (gravity).

i = the hydraulic grade.

$$\beta = \log \frac{Q}{\sqrt{gi}}\left(\frac{14}{(\propto T + k_0)^{\frac{5}{2}}}\right)$$

k_0 = 0.01 inches.

$\propto$ = rate of growth of roughness,

$$= \frac{3.7d}{T}\left(10^{-p} - 10^{-p_0}\right)$$

$$p = \frac{C}{2\sqrt{8g}}$$

$$p_0 = \frac{C_0}{2\sqrt{8g}}$$

C = Chezy coefficient for old pipe.

C_0 = Chezy coefficient for new pipe.

—*H. E. Babbitt.*

Formulas and Tables for Computing Cylinder Intersections. Louis J. Sack. Eng. News-Rec., 119: 1063 (Dec. 30, '37). Computing volume at intersection of cylinders, e.g., at intersection of circular shaft and tunnel of same or different diameters or at tees and wyes, is problem that frequently arises. General method used is to compute volume of each cylinder and deduct volume

which has been included twice. Object of article is to derive an expression for this common volume. Mathematical solutions of some of more common cases arising in practice are given and tabulated values for computation to high degree of accuracy with minimum amount of labor are derived.—*R. E. Thompson.*

HYDROLOGY, FLOODS AND FLOOD CONTROL

Near Record Rainfall in New Orleans. ANON. Eng. News-Rec., 119: 581 ('37). Rainfall amounting to 14:25" between 2:45 p.m., Oct. 1 and 8 p.m., Oct. 2, which is equivalent to ½" of rainfall per hour, flooded large areas of New Orleans, capacity of drainage system (much of city is below sea level) being considerably exceeded. The rain continued intermittently until afternoon of Oct. 3, reaching all-time 48-hour record of 16.65". In '27, 14.1" of rain fell in 24 hrs.—*R. E. Thompson.*

Some Flood Producing Storms of the Atlantic Seaboard. MONTROSE W. HAYES AND HORACE R. BYERS. J.N.E.W.W.A. 51: 207 (Jun. '37). In estimating probable max. flood flows for any area it has been customary to superimpose some particularly heavy rainstorm on the watershed in question. The storms of May 30 to June 1, 1889; Nov. 2 to 4, '27; July 7 to 9, '35 and that of Mar. 17 to 20 '36 are briefly discussed from standpoint of rainfall and cause of subsequent floods. The last named was remarkable in that flood producing rains fell over an unprecedentedly large part of the Atlantic slope. These rains fell on well-saturated and semi-frozen soil or, in elevated regions, on snow of high water content. Resulting floods most disastrous of record in the James, Potomac, Susquehanna, Connecticut, and Merrimac Rivers, in some of tributaries of Ohio rivers and in the Ohio from Pittsburgh, Penna, to below Wheeling, W. Va.—*Martin E. Flentje.*

New England Droughts and Floods in Their Relationship to Water Supply. CALEB MILLS SAVILLE. J.N.E.W.W.A. 51: 327 (Sep. '37). Because of relation to Hartford, Conn. water supply recent unusual excess and deficiency of rainfall is important. Paper supplements previous papers by author on same subject placing recent experiences on record. Hartford rainfall records cover 75 yrs. with streamflow records for approx. 25 yrs. Max. rainfall of 56.95" occurred in '20 and min. of 28.90" in '35. Most common cause of floods and and droughts is found in the general circulation of the atmosphere with its cyclonic (lows) and anticyclonic (highs) phenomena found in the march of barometric depressions from west to east in temperate zone. In general, depressions pass to west and north of New Eng. and out through St. Lawrence Valley, or up Atlantic Coast and out to sea before reaching section. When diversion from these general paths takes place and the depressions are forced toward New Eng. storm and floods may follow. Period 1892–96 and 1936 were some of the great drought periods in many parts of U. S. but not of particular moment to Hartford's water supply. Hartford's dryest period occurred in 1879–83 while rainfall during same period at New Haven, 30 mi. south, was above normal. To make reliable estimate it is necessary to have rainfall records covering at least 50 yrs. 100 yr. Hartford mean rainfall is 43.44" (using

relationships to longer records). Computations of 5 and 20 yr. running averages indicate there have been 4 periods of extremely low rainfall, centering in about 1846, 1881, 1911 and 1931, the percent rainfall of av. being respectively: 79.6, 77.1, 81.5 and 66.2%. Recent drought period for Hartford began about middle of '29 and ran well into '33. Computations and graph show effect of this period on Nepaug Res. of Hartford supply with drainage area of 32 sq. mi. and cap. of 9.54 billion gal. if rates of 23 and 25 m.g.d. had been encountered instead of present av. of 18.24 m.g.d. 25 m.g.d. would have exhausted supply, and additional supply works are now under construction. New Eng. floods, like droughts, caused by storms leaving usual path of travel. Present floods cause more damage than earlier equal or larger floods because streams now more confined with subsequent less available storage in low lands along banks. Streamflow records on E. Branch of Farmington R. for yrs. '13–'36 show max. peak flood flow of 141.8 c.f.s. per sq. mi. and 24 hr. flow of 95.50 c.f.s. with rainfall of 6.52″ (Nov. 2–4, '27); peak of 135.8 c.f.s. and 24 hr. flow of 98.0 c.f.s. with rainfall of 6.83″ (Mar. 11–20, '36); lowest yearly maximum during the period was 11.58 c.f.s. in Mar. '18. Of the two greatest floods, one occurring in Nov. '27 was due solely to rainfall at that time, other of Mar. '36 was caused by rainfall and removal of snow and ice on watershed at same time. Items of interest of Mar. '36 storm are estimated to be (1) 62 sq. mi. East Branch Watershed: rainfall (Mar. 11 to 26) 8.14″, run-off 11.7″, peak flow 135 c.f.s. per sq. mi.; (2) 32 sq. mi. Nepaug Watershed: rainfall, 6.95″, run-off 8.8″, peak flow 98 c.f.s. per sq. mi. These flows as well as other great floods were used in designing a new water supply res. for Hartford on E. Br. of Farmington R. at Barkhamsted to have a cap. of 30 billion gal. or 92,000 acre-ft. Dam is 136′ high above original river bed. Below this res. is another 3 billion gal. res. and below this several populous high property value mfg. communities to which absolute protection from floods had to be given. Flood peak provided for in new work was 500 c.f.s. per sq. mi., providing for a chance expectancy of about 1 in 1000. A rather complete statistical and factual study is given of the Great Flood of '36 in the Farmington R. and in the Conn. R. at Hartford. For easy visualization of quantities of water passing during the flood, author gives following relations: (1) during the 24 hrs. of max. flow there passed down the river at Hartford sufficient water to have covered Hartford (17 sq. mi.) to a depth of 54′; the Metropolitan Dist. (100 sq. mi.) to a depth of 9′; and the State of Conn. (5000 sq. mi.) to a depth of 2″. The entire flood flow would have covered the State of Conn. to a depth of 2′. (2) By another analogy, it is estimated that sufficient water passed to have filled Barkhamsted Res., now under construction, 65 times and to have supplied Hartford Metropolitan Dist. requirements for 300 yrs. at present rate of demand. Various methods of flood control and protection as affecting Hartford are discussed.—*Martin E. Flentje.*

Meteorological Conditions During the March 1936 and Other Notable Floods. Horace R. Byers. J.N.E.W.W.A. 51: 210 (Jun. '37). Consideration is given to various floods from viewpoint of the aerial phase of the water cycle belonging to meteorologists. Air-mass system of meteorological analysis is based on an attempt to investigate the exact physical processes involved in the weather. In various sections of the earth the air acquires properties of

moisture and temp. characteristic of that section and are called air masses. Because of density differences when two masses come together, a discontinuity occurs which is called a front. If a cold air mass advances over territory formerly occupied by warm air the resulting front is called a cold front, in a similar manner advancement of a warm air mass is designated a warm front. If a cold front overtakes a warm front and forces warm surface air to a higher level an occluded front occurs. Cold fronts are often identical with squall-lines or wind-shift lines. Along fronts a lifting of the warmer air takes place. This results in rapid expansion of the warm air with subsequent cooling. If cooled enough condensation takes place causing rain. Interaction of air masses along fronts produces low pressure areas which now no longer form basis of weather forecasting. The 1889 Johnstown flood, N. Y. State flood in '35, New England floods of '27 and '36 are discussed from meteorological standpoint. Author states that it is reasonable to believe rainfall as great as occurred in the Johnstown flood is not to be expected under conditions of appreciable thawing. 9 weather maps are included.—*Martin E. Flentje.*

Flood Runoff from Small Areas. VICTOR H. COCHRANE. Engs. News-Rec., 119: 864 (Nov. 25, '37). Very few of the numerous flood formulas which have been proposed are applicable to small drainage areas and some give values 10 to 20 times too small for extreme cases of intense precipitation and rapid runoff. New formulas, which eliminate these inaccuracies, are given. The formulas are based on the variation in rate of precipitation with respect to time and give results approximating those obtained by use of the so-called rational method.—*R. E. Thompson.*

Weather and Water Supply. E. B. BILHAM. Surveyor (Br.). **92:** 701 (Dec. 3, '37). (Extract from paper read at Public Works and Transport Congress.) In England and Wales, in the last 36 years, only six years have yielded less than standard average rainfall. Since 1891 no two dry years have come in succession. A drought like that of the fifties of the last century would be a new experience for water undertakers of today. A statistical analysis of the data for the period '14–'36 shows that the annual run-off (F) is very closely correlated with the annual fainfall (R) in the form $F = 0.57R - 6.05$ for the Thames watershed. In the Severn watershed the relation is $F = 0.57R - 6.66$. It is clear that, for the purpose of water supply, conditions in the Severn are more favorable than in the Thames. The conclusion is reached that rainfall is the main factor in the determination of run-off.—*H. E. Babbitt.*

Modernizing Headwater Forecasting. MERRILL M. BERNARD. Eng. News-Rec., 119: 988 (Dec. 16, '37). Federal responsibility for providing flood forecasting service in flood plains of larger rivers was recognized nearly 70 years ago but as headwaters are approached and the problems become more and more localized responsibility shifts in varying degrees to other interests. Likewise, methods which have been successful on lower reaches of rivers must be elaborated to take into account the many factors influencing smaller streamflow. Pennsylvania has been among first to recognize this trend and in cooperation with U. S. Weather Bureau and U. S. Geol. Survey means have been provided

to establish modern forecasting service on Allegheny, Monongahela, Susquehanna and Delaware Rivers. Plans for this service, which are described, are in many respects unique. First step in program was establishment on river basins of a net of approx. 130 recording rain gages having av. density of 400 sq. mi. per gage. Locations of these stations are shown on a map. Including the 500 recording rainfall stations recently established on Muskingum watershed, there is now a continuous net of closely spaced recording gages covering greatest area so served in this country. Plan also provides for installation of about 15 additional streamflow stations of recording type. Procedure to be followed at a typical forecasting center is outlined. Project has full support of the various government services and promises to set a new standard of coöperation between federal and private agencies, utility companies making available for transmission of data their dispatching and communication facilities. Recent developments in transmitting equipment are timely and will be of great benefit in such projects in bringing to forecasting centers data from remote index stations. Of particular interest in this connection are the automatic telephonic and radio stage transmitters. The Tennessee Valley Authority is utilizing radio for transmitting rainfall depth from remote stations.—*R. E. Thompson.*

Forecasting Rainfall by Mean Seasonal Distribution. H. Wenderoth. Civ. Eng. 7: 770 (Nov. '37). The rainfall data for each of the stations for the rainfall year are tabulated by monthly accumulation. The percentage that each month is of the total accumulated rainfall for each year is next computed. Then the mean rainfall for each month for the entire period is obtained and the mean accumulated percent is calculated. From these data a chart is prepared for each station. The use of the curves in these charts makes possible predictions which are close enough to be of practical value.—*H. E. Babbitt.*

River Control and Flood Prevention. S. D. Foote. Can. Engr., 73: 23:7 (Dec. 7, '37) and 73: 25: 9 (Dec. 21, '37). An extensive discussion of river control including calculation of runoff from watersheds by unit graph method, flood control practices and the factors governing transportation of solids by streams and their subsequent deposition. Unit graph method has advantages over other procedures and enables runoff record to be computed when only limited streamflow data are available. It should be recognized, however, that it is based on fundamental assumptions that are not strictly true and that results are only approx. correct. Of the 4 major flood control methods, (1) levees, (2) enlargement of channel capacity by straightening, widening, deepening, etc., (3) auxiliary or emergency flood channels and (4) reservoirs, the first is most direct and surest. Methods employed on Po River in Italy, possibly the oldest and greatest river control project in the world, are described and discussed and lessons to be learned therefrom are outlined. The proposed Grand River Valley project in Ontario is discussed in some detail. Objectives of plan include prevention of floods, raising of ground water levels and maintenance of sufficient flow during low water periods to provide adequate dilution of sewage effluents and ensure that quality of river water is such that it can be

purified by modern methods of water treatment. Pollution by industrial wastes and domestic sewage, combined with low summer flows, has created condition which necessitates the adoption of remedial measures. It is proposed to construct 4 impounding reservoirs of 10,000 acre-ft. capacity each on Grand and Conestoga Rivers and low dam to back the headwaters of the river at its outlet from Luther Marsh. These works, cost of which is estimated at $1,359,000, would provide sufficient storage to reduce ordinary floods to limits below capacity of present protective facilities. By construction of one additional dam on each of the rivers, at estimated additional cost of $1,596,000, a flow sufficient to meet needs of a population some 3 times that of the present could be provided and protection secured against any flood likely to occur.—*R. E. Thompson.*

DAMS

Arch vs. Gravity Dams. ROBERT A. SUTHERLAND. Eng. News-Rec., **119**: 848 (Nov. 25, '37). Brief discussion of relative merits of arch and gravity dams. Considering only sites which are suitable for either type, author believes that use of arch principle has definite and inherent advantages in addition to economy: (1) Stability of gravity dam depends mainly on weight and effective weight can be seriously reduced by uplift and tailwater, neither of which has serious effect on arch dams. (2) As water load increases, factor of safety of gravity dam decreases as square of depth of water, while that of arch dam decreases to much less extent. (3) Arch dam acts as a whole and minor weakness in one part of foundation results in some part of load being transferred to stronger parts, while each section of the length of gravity dam must "stand on its own feet." Records would seem to justify conclusion that arch dams have inherently greater reserve strength.—*R. E. Thompson.*

Earthquake Stresses in an Arch Dam. I. M. NELIDAY AND H. E. VON BERGEN. Proc. A.S.C.E. **63**: 1851 (Dec. '37). Formulas are derived for determining the stresses due to the horizontal effect of an earthquake on an arch dam when the acceleration of the earthquake is assumed to occur across the canyon, and secondly when it occurs at right angles to the first condition. Arches with fixed as well as with hinged ends are considered and illustrative numerical examples are solved. An earthquake which accelerates the dam up stream produces stresses that seldom exceed about 10% of the water-load stresses; but for an earthquake acting across the canyon the stresses may be quite large. The less the central angle the less vulnerable will the arch be for cross-wise acceleration.—*H. E. Babbitt.*

The Design of Rock-fill Dams. J. D. GALLOWAY. Proc. A.S.C.E. **63**: 1451 (Oct. '37). A rock-fill dam is one made up of loose rock forming the mass of the dam, an impervious face next to the water that may be made of timber, steel, or concrete, and a mass of rubble placed between the loose rock and the face. The material composing the body of the dam should be a hard, solid rock, free from joints that would permit the rock to fracture under load and where the crystalline structure has not been broken down by earth stresses. Although rock-fill dams are not the most stable type there are a number of

reasons for their adoption. Dams have stood where the base was little more than twice the vertical height, but the section should be such that the ratio is greater. All rock-fill dams settle over a long period of years, although the major settlement occurs in the first years. The design of rock-fill dams is a matter of judgment based upon experience.—*H. E. Babbitt.*

Algerian Dams of Placed Rockfill. I. GUTTMANN. Eng. News-Rec., 119: 889 (Dec. 2, '37). A detailed description of the construction of 4 rockfill dams (Bakhadda, Fum-El-Gueiss, Ghrib and Bu-Hanifia) included in current irrigation program of French government in Algeria, which indicates trend toward standardization on new lines. Dumped fill is definitely abandoned, all rock being machine and hand laid. Exhaustive precautions are taken to control seepage and underflow by barriers and elaborate provisions for drainage. These unusual precautions are probably due in part to the unfortunate experience with the Wed Kebir rockfill dam, 112′ high, built in '22–'25 for Tunis water supply. This dam, famous for its hollow multiple-arch concrete core set vertically in center of a loose rock fill, suffered partial failure in flood of '29, when corewall sheared off the cutoff wall and deflected downstream. It was repaired during '30–'31 and successfully withstood similar flood a few months later. All 4 dams have inclined impervious decks (2 of reinforced concrete and 2 of bituminous concrete), heavy cutoff walls carrying inspection tunnels for their entire length, and deep grout curtains upstream of cutoff walls. Slope of downstream faces is 4:5 and upstream faces are of variable slope vertically concave. Height of dams varies from 75.5 to 233′, crest length from 722 to 1510′ volume of rock fill from 170,000 to 1,000,000 cu. yds., freeboard from 12 to 21.6′ and cost from $3,000,000 to $22,000,000. Placing of rock fills and construction of impervious decks are dealt with in detail: subsequent article will describe underground structures.—*R. E. Thompson.*

WELLS AND GROUND WATER

Explosive Gases Found in City Water Supply. ANON. Eng. News-Rec., 119: 874 (Nov. 25, '37). Following explosion in settling basin of Clinton, Ill., water works, which caused considerable property damage, investigation by Bur. of Mines disclosed that water supply, derived from deep wells, contained methane. Methane was also found in water supplies of schools in nearby town of Wapella: a janitor had been severely burned several months before by explosion in basement of a school. To reduce hazard, Bureau suggested complete aeration, use of "permissible" enclosed motors on pumps, efficient ventilation of enclosed settling tanks and prohibition of smoking in pump rooms or near tanks. In regard to school supplies, recommendations include location of wells at least 200′ from building and complete aeration at or near pump house before water enters pressure tank. Origin of methane is decomposing glacial peat beds, water being sealed under pressure in contact with carbon dioxide, ammonia, methane and traces of hydrogen sulfide in adjacent sand and gravel bed.—*R. E. Thompson.*

Methods of Locating Salt-Water Leaks in Water Wells. PENN LIVINGSTON AND WALTER LYNCH. Water Supply Paper 796-A, U. S. Geol. Survey, ('37).

Contamination of water supplies with highly mineralized salt-water is of importance in water to be used for irrigation, boiler-feed, ice-making, and other industrial uses as well as in water for domestic use. The appearance of such contamination raises question as to whether salt water has gained entrance to the water-bearing strata or whether contamination is occurring through leaks in well casings. Four general methods of locating salt-water leaks are available—pumping, velocity, sampler, and electrical-conductivity methods. Pumping method consists of pumping well and noting changes in salt content of discharge as pumping progresses; applicable only to wells that can be pumped readily or that have natural flow. By plotting time of pumping against chloride content and noting appearance of high salt conc. it is often possible to deduce approximate location of casing leak or to determine if entire water bed is contaminated. The velocity method depends upon the use of a sensitive current meter to determine the location of higher than normal velocities caused by entrance of contaminating water. An Au deep-well current meter is briefly described together with some experience with its use. In the sampler method samples are taken at different depths in the well for chemical analysis. A sampler consisting essentially of an 18″ length of 3″ galv. pipe, provided with a leather flap-valve at the top and bottom, has been found satisfactory. Representative sample at any depth is obtained by rapidly moving sampler up and down through approx. 1′ distance for about 10 up-and-down movements. The chloride content of the individual samples plotted against the depth at which taken gives indication of location of leak. The flap-valve sampler is satisfactory for non-flowing wells and perhaps for wells having small flow but is not adapted to wells with strong flows. For this type another sampler is described. In the electrical conductivity method the salinity of the water is determined by measuring its conductivity, the conductivity increasing with an increase in dissolved solids. Two electrodes are lowered into well to be tested and degree of conductivity of water between them determined by either a Wheatstone bridge to measure resistance of water to current or a milliammeter to measure the direct current between the electrodes. Complete water tight insulation of wiring system and electrodes is necessary. Recommendations are made for proper construction of wells—well should be cased with good grade genuine wrought iron, or cast iron; casing size reductions should be as few as possible, protection against corrosion provided for, wall of mud, and concrete around bottom, should be provided to keep salt water from metal.—*Martin E. Flentje.*

Industry Taps an Underground Lake. C. M. Maratta. Eng. News-Rec., 120: 25 (Jan. 6, '38). A ground water collector, believed to be the largest ever built, was recently placed in operation at the Canton, Ohio, plant of Timken Roller Bearing Co. Collector is of the radial well type and consists of a shaft, 147.5′ deep, from bottom of which screen pipes were driven radially on a horizontal plane. Previously, plant was dependent on 24″ vertical wells. Water is pure and wholesome but has a hardness of 365 p.p.m., about half of which is carbonate. Owing to high mineral content well screens had a short life (3-8 yrs.) and a new well had to be drilled on an av. of every 18 mo. Incrustation is believed to have been due to liberation of carbon dioxide, as result of

release of pressure or change in temperature, which allowed deposition of mineral matter on screens. In new well it is believed that screens will at all times be under same pressure and temperature and that, with low water velocity through screen area, incrustation will be substantially eliminated. Collector has internal diam. of 12.5′ and is lined with air-applied concrete and sheet steel. Screen pipes were made from ⅜″ copper bearing steel plate punched flat with 1½″ x ¼″ slots, then formed into semi-circular sections and welded into 8″ pipe. An inner sand pipe allowed fine sand to flow into well as screen pipe was driven and served as a means of creating water jet action to loosen formation ahead of digging point. Sand removed averaged 3 cu. ft. per lineal ft. of screen pipe projected. The 36 screen pipes varied in length up to 175′ (limit set by property lines), aggregate length being 2800′. Total open area in screen pipes amounts to 1120 sq. ft. and water velocity through screen openings when pumping 10,000 g.p.m. is about 0.019 ft. per sec. Four deep-well vertical motor driven pumps are now in place 75′ below ground surface in collector shaft and another will be installed. Combined capacity of the 5 pumps will be 11,600 g.p.m. against total head of 180′. Motors are located in pumphouse at top of shaft. Average draw-down is 7′ when pumping 7,500 g.p.m. at present time. To enable unwatering of shaft for inspection and repair and to permit use of full head of water available for flushing screen pipes, each of the 36 port holes through which screen pipes were projected was equipped with 10″ flanged gate valve. Each valve stem, weighing 300 lb., is supported on tapered roller thrust bearing, relieving valve of all weight and resulting in easy operation even though 136′ below surface. Assuming a continued static water level as at present, it is estimated that collector could produce 20 m.g.d. At this rate, velocity through screens would be about 0.028 ft. per sec. and draw-down would probably be not more than 15′.—*R. E. Thompson.*

DISTRIBUTION—MAINS, VALVES AND RESERVOIRS

Economic Pipe Sizes for Water Distribution Systems. T. R. Camp. Proc. A.S.C.E. 63: 1837 (Dec. '37). The economic pipe sizes for a gravity system will be one set that utilizes all the available head in friction when delivering the peak flow to each critical point in the system. The relation between the slopes of the hydraulic grade lines of any two connecting pipes in a gravity series for best economy can be expressed mathematically. Mathematical expressions are also given for the economic diameters of pipes through which water is pumped at a constant rate against a constant head, at a constant rate against a varying head, at a varying rate against a constant head, and at a varying rate against a varying head. Notwithstanding the fact that many engineers have been accustomed to thinking of the economics of pipes in terms of velocities, the practice is valid only in very special cases.—*H. E. Babbitt.*

Solution of Transmission Problems of a Water System. E. H. Aldrich. Proc. A.S.C.E. 63: 1511 (Oct. '37). Water distribution system problems usually involve the simplification of intricate arrangements of many pipe lines and their combination into one or more equivalent pipes. Where simple combinations are involved the solution is easily made with the aid of the

hydraulic slide rule. The addition to the problem of "put-ins" and "take-outs" involves complications requiring the use of head-capacity curves for each pipe which are shifted about in a graphical method of solution. In this manner problems involving "compound storage" and pipes with intermediate "cross-overs" can be solved. A solution of a general problem is presented as an example of the application of the method.—*H. E. Babbitt.*

Water Supply for the World's Fair and Its Later Service. ANON. Am. City. 52: 11: 68 (Nov. '37). As the New York World's Fair site will eventually become Flushing Meadow Park, the design of the water supply system had to take into consideration both temporary and permanent facilities. In exchange for free water during the Fair, the Fair authorities are supplying $240,000 worth of permanent mains. Outstanding differences in the needs for the two distinct uses (temporary and permanent) are that the World's Fair will need large quantities available for fire protection, while the Park Department will need very little for that purpose. On the other hand, the Park Department will need large quantities for irrigation which will not be necessary in the World's Fair where a large part of the area will be covered with buildings. To accomplish this dual aim, the smaller mains of the World's Fair system (6" and 8") were made permanent and the larger ones temporary. The irrigation system will be large enough to provide 1" of water over the entire area in a week and the showers and comfort station facilities are designed with a view to peak loadings. Data for design were available from the experience of the Chicago Fair and indicated a maximum hourly rate of 25.61 m.g.d.—*Arthur P. Miller.*

Pumps and Pipes Serve Three Objectives. A. P. MALLEY. Eng. News-Rec., 119: 1050 (Dec. 30, '37). The factors governing the design of the water supply system for the Golden Gate International Exposition, to be held on a newly-built, 400-acre island in San Francisco Bay which will subsequently be used as an airport, are dealt with in some detail. The system, which will also serve the adjoining Yerba Buena Island and the fire protection system on the San Francisco Bay Bridge, must be capable of delivering 1.8 m.g.d. on normal days and 2.5 m.g.d. on peak days during the 288-day exposition and, when site is converted to an airport, easily adapted to continuously supply economically only 0.25 m.g.d. Suitable site was selected on Yerba Buena Island for 3-mil. gal. reservoir with high water elevation of 260′ above sea level from which water could be delivered by gravity. Reservoir will be supplied from city mains by pumping station built in recess of pier at San Francisco end of bridge, delivering into pipe line carried on bridge (cf. This J., 29: 2050). Water required on Yerba Buena Island, estimated at 0.15 m.g.d., will be delivered by 400-g.p.m. float-controlled pump from new reservoir to existing reservoir about 70′ higher. Pumping equipment will consist of: (1) Two 175-g.p.m. pumps to operate permanently in supplying needs of Yerba Buena Island and the airport subsequent to exposition period; (2) 1250-g.p.m. pump for normal consumption of exposition and for fire protection on bridge, which also will be permanent installation; and (3) 1700-g.p.m. pump for supplying water to exposition on peak days, which will be used only during exposition. After

comparative studies of construction and pumping costs had been made, 10″ cement-lined pipe was selected for bridge pipeline. Surge compressor tanks, directly connected to suction and discharge pipe manifolds, were installed to minimize shocks incidental to starting and stopping of pumps. All motors will operate on 440-volt, 60-cycle current. Operator will be stationed in pumping station during exposition to maintain required water level in reservoir as indicated by telemeters but after exposition it is planned that operation will be entirely automatic.—*R. E. Thompson.*

New Developments in Welding of Building and Industrial Piping. Anon. Eng. Cont. Rec., **50**: 102 : 7 (Dec. 8, '37). The present scope of pipe welding is reviewed and developments of recent years are described. There are now available valves and expansion joints with cast or wrought steel ends for welding directly to pipe. Thus, if desired, all flanges may be eliminated. Welding elbows, tees, reducers, etc., have been available for a number of years; systems of closed tubes equally strong in all parts are therefore possible. Welding specifications usually include method of welding, sizes of pipes to be welded, fittings, grade of welding rod, preliminary test of welds to determine workmen's ability, preparation of joints for welding, welding procedure and final test. For greatest efficiency, careful organization of erection phases of work is important.—*R. E. Thompson.*

Multi-Lengthening Cast Iron Pipe by Welding. C. L. Lane. Can. Engr., **73**: 25 : 5 (Dec. 21, '37). The procedure employed at the Attalla, Ala., plant of Walworth Co. for multi-lengthening of cast iron pipe by welding is described. Pipe of 3 standard analyses for varying degrees of corrosion is manufactured in sizes from 1½″ to 8″. All are furnished with threaded ends for connecting with loose couplings or with one end threaded internally and other externally for connecting without separate couplings. In addition, pipes threaded one pipe-size larger than pipe itself are available: also sections with flexible gasket type joints for insertion at intervals to allow for expansion and contraction, ground movement, etc. All pipe is cast horizontally in 5′ sections and welded into longer lengths as required by the oxy-acetylene process. Chief factor in producing satisfactory results is to keep weld hot until entire joint is completed. Most difficulties with welding cast iron pipe in field can be attributed to failure to cool the weld uniformly or failure to "get bottom" while welding. Pipe metal must be melted for distance of about $\frac{1}{16}$″ right down to bottom of bevel, at same time adding molten welding rod metal (same metal as pipe) so that it unites with fused metal on either side. Welded cast iron pipe is now accepted without hesitation by users and there are thousands of tons in successful service. Laterals, manifolds, bends and special fittings are also fabricated by this process.—*R. E. Thompson.*

Experience With Transite Pipe. A. B. Rich. J.N.E.W.W.A., **51**: 289 (Sep. '37). P.W.A. project provided complete water supply for Sterling, Mass. in summer of '35 consisting of driven wells, pump station, stand-pipe, distr. system, etc. Transite pipe with c.i. fittings used for mains. This pipe can be laid much faster and more easily than c.i. pipe and joints can be made

in either wet or dry trench. Small particles of silt or clay in trench water sometimes give trouble in pulling couplings into place. Pipe laid below water must be weighted down to prevent floating. More care must be given in back-filling and stones must not be dropped on pipe. Bends, tees, dead ends, etc. must be backed or shored up to take full unbalanced loads that may come upon them because flexible joints offer practically no resistance to these forces. Pipe can be cut with ordinary wood saw and usual tools used for tapping for services. 19,000′ of 6″, 8″ and 10″ transite pipe at Sterling tested under 80 to 175 lb. pressure showed couplings made water-tight joints. Of 1839 pieces of pipe tested no single length showed any signs of sweating under pressure. Of 1607 Simplex couplings only 2 leaked. Williams-Hazen "C" found to range from about 145 to 150. In pressure tests made on this system under 150 to 265 lbs. per sq. in. several lengths of pipe burst under high pressure apparently due to defective sections. Of 1839 pieces of Transite pipe tested for breakage 33 lengths failed, 2 of Simplex couplings failed and 3 of 3214 rubber rings blew out. Author concludes factory tests of 260 lb. hydrostatic pressure is insufficient for pipe for working pressure of 130 lb., believes factory pressure should be 600 lb. per sq. in. Transite pipe should not be stressed beyond 90% of its ultimate strength. Among advantages of pipe are its light weight—can be laid rapidly with fewer men, negligible joint leakage, no loss of capacity due to tuberculation, coefficient is high and should remain so, has considerable flexibility. One major disadvantage is lack of sufficient strength to withstand rough treatment. Several tables giving results of leakage tests, flow tests, surges, and pressure failure tests are given.—*Martin E. Flentje.*

Our Introduction to Transite Pipe. HAROLD L. BRIGHAM. J.N.E.W.W.A. 51: 285 (Sep. '37). Introduction to Transite pipe secured through laying 2000′ of 6″ main in summer of '36 in narrow winding road with steep slopes on sides and with digging largely through ledge. Pipe not stored on job to prevent damage by flying rock during blasting. Leakage tests made on each day's laying by connecting short section of pipe with ordinary cast iron sleeve to end with compound joint and in end of sleeve was installed a plug carrying a ¾″ curb cock. In back filling entire line tamped with railroad tamping bars under and up to horizontal diam. with care to have no stones touching pipe. On first day in previously excavated trench 22 men laid 500′ of pipe, back filled ½ of trench and tested line in 6½ hrs., second day in ledge 400′ pipe was laid and line tested in 5 hrs. Pipe tested at 120 lb. pressure with no leaks first day, one cracked collar found on second. Several dented pieces of pipe found which were rejected, on tests these withstood 600 lb. per sq. in. hydrostatic test with no indication of failure at 780 lb., a 5.2 factor of safety for Class 150 pipe. Several days after installation lime or cement taste was complained of which was eliminated by installation of a small bleeder at end of line.—*Martin E. Flentje.*

Underwriters' Tests of Transite Pipe. CHARLES W. SHERMAN. J.N.E. W.W.A., 51: 282 (Sep. '37). Quotations from Report No. Ex. 1251 by Underwriters' Laboratories Inc. on Transite Pressure Pipe and Couplings dated Jan. 20, '37, approving "Class 150" Transite "Pressure" Pipe and Transite

"Simplex" Couplings for use in public and private water works and in fire-service systems and connections to such systems where working pressure does not exceed 150 lb. per sq. in.—*Martin E. Flentje.*

The Value of a Valve Record. M'Kean Maffitt Eng. News-Rec., 119: 831 (Nov. 18, '37). Systematic mapping of valve locations is as important as installation of the valves. Valves that cannot be found immediately when needed are little better than useless. In Wilmington, N. C., valve locations are referenced to 2 or more permanent objects. Record system includes key map, section and corner maps. Key map, which has scale of 1:1000, is marked off into sections, which are numbered. Section maps, each covering average of 16 squares or blocks and overlapping adjoining sections, are made to scale of 1:100. On these are shown locations of hydrants, valves and mains, together with general data that will enable approximate location of principal objects to be determined at a glance. Corner maps, on scale of 1:10, show detailed data for each corner in city. The maps, in loose-leaf binders, are carried on repair trucks. In addition, valve and hydrant record books are maintained giving complete information, such as size, make, specifications and historical and operating data. Present practice is to place valves on hydrant branches at the main rather than at the hydrant, experience having shown that valves at latter point are often disturbed when hydrants are damaged or are rendered inaccessible by damage of hydrants. Examples of maps used are illustrated.—*R. E. Thompson.*

Bacterial Disintegration of Sulfur-Containing Sealing Compound in Pipe Joints. T. D. Beckwith and P. F. Bovard. Univ. Calif. (Los Angeles) Pub. Biol. Sci., 1: 121 ('37). Commercial preparations containing sulfur used for sealing joints in water mains may be disintegrated under certain conditions by the activity of certain bacteria which are relatively resistant to chlorine-ammonia treatment of water. Aerobic thiobacteria oxidize the sulfur to sulfuric acid, and sulfates are formed. These are reduced to hydrogen sulfide by anaerobic bacteria and the hydrogen sulfide combines with the iron of the pipe to form ferrous sulfide.—*R. E. Thompson.*

New Pipe Hanger Saves Breakage. Anon. Eng. News-Rec., 119: 1026 (Dec. 23, '37). Experience with breakage of pipe hangers in Cedar Rapids, Iowa, led to design of new type which was used in hanging 16" water main under bridge consisting of six 103' clear span arches. The hanger is illustrated and erection procedure outlined.—*R. E. Thompson.*

Cast Iron Bid is Low at Corpus Christi. Anon. Eng. News-Rec., 119: 842 (Nov. 25, '37). Lowest tender on 81,950' of 30" pipe line for Corpus Christi, Texas, water system was for tar-coated cast iron pipe with cement joints, unit prices being \$7.62 per foot for Class I pipe was \$7.18 for Class II pipe, total tender being \$620,000. Consulting engineers have recommended acceptance of this bid and that sufficient money be allocated for cement-lined instead of tar-coated pipe. Lowest tender on this alternative was \$7.97 and \$7.52 per foot for Class I and II pipe, respectively, totaling \$648,000. Low bid on

enameled steel pipe was $624,000 unit, price being $7.31 per foot. Low bid on enameled and wrapped steel pipe was $8.27 per foot. Low tenders on lead-jointed cast iron pipe were $649,000 for tar-coated and $677,000 for cement-lined.—*R. E. Thompson.*

DISTRIBUTION—METERS AND SERVICES

Master Meters. Harold W. Griswold. J.N.E.W.W.A., **51:** 203 (Jun. '37). A mechanical rate recorder is used in Hartford Conn. to detn. whether or not compound meters in service are of the proper size for max. demand and minimum loss of revenue, and to detn. if a battery of single meters having same capacity will be more accurate. Device used provides a chart for study and 3 investigations in which this meter was used are cited.—*Martin E. Flentje.*

Use of Water Meters in Municipal Service. Anon. Can. Engr., **73:** 26:10 (Dec. 28, '37). Data, compiled for Waterworks Information Exchange of Canadian Section of American Water Works Association, are given showing, for municipalities in Canada, the percentages of (1) residential and (2) industrial or commercial services metered, together with percentage of water delivered through meters and percentage of revenue derived therefrom. Part of this tabulated data appeared also in Eng. Cont. Rec., **51:** 2:13 (Jan. 12, '38). —*R. E. Thompson.*

The Pirelli Lead Extruding Machine. Anon. The Eng. (Br.). **164:** 609 (Nov. 26, '37). Lead water pipes were made by an extrusion process at a very early date. The earliest recorded patents were taken out in England in 1797. In service the behavior of lead pipes has been found to be extremely variable. Investigations have shown that in certain cases the failure of lead piping was was due to the inability of lead to stand up to alternating stresses caused by vibrations. It has also been shown that the majority of pipe failures can be attributed to the inclusion of oxide films in the lead pipe walls. The Pirelli lead extruding machine is continuous in its operation and produces sheathing free from lead oxide.—*H. E. Babbitt.*

Electric Grounding on Water Pipes. J. O. R. Coleman. J.N.E.W.W.A., **51:** 277 (Sep. '37). Custom of maintaining electrical circuits completely isolated throughout customers premises established in time of d.c. system gave difficulties when applied to a.c. circuits. Grounding of secondary circuits on customers premises appeared to offer most practical way of eliminating hazard to life and danger from fire resulting from high voltages that may accidentally be impressed on secondary wires. Grounding of this type mandatory since '13. Water pipes make best ground not because of contained water but because water system has by far largest contact surface with conducting material of earth. Lighting circuits usually protected with 15 amp. fuses. Circuits for kitchen ranges and water heaters frequently have 60 amp. fuses, and main service fuses are seldom over 100 amp. with present method of wiring and grounding. In case of contact between primary and secondary, or of a transformer breakdown, the potential within premises is limited and a positive path is provided for fault current promptly to deenergize the circuit. Like-

wise, for a short circuit in house wiring, a positive path is provided and the secondary fuse clears the circuit. Might be possible to have full secondary voltage across opening for meter, when meter removed, but possibility of such combination of circumstances occurring seem remote. Placing of insulating joints in water pipe makes little difference in effectiveness of grounding of secondary services. Primary purposes of limiting differences of potential within the premises is still accomplished and with a number of such services, averaging 20 or 30 in parallel, a low resistance ground is obtained to provide protection against the primary voltage. First objections to grounding were made for fear of electrolytic corrosion, however tests proved electrolytic action of a.c. current negligible compared with effect of d.c. On such basis A.W.W.A. approved grounding of secondaries of lighting transformers on water pipes for practical purposes, which was rescinded in May '35 because of recent experiences involving shocks received by employees or customers and taste and odor conditions in several places thought caused by stray currents. Discussion following resulted in formation of Amer. Research Comm. on Grounding in which number of interested associations are represented. This Comm. now engaged in study of problems.—*Martin E. Flentje.*